State of Arizona Exceptional Event Documentation for Wildfire-Caused Ozone Exceedances on June 20, 2015 in the Maricopa Nonattainment Area

Produced by:

Arizona Department of Environmental Quality
Maricopa Association of Governments

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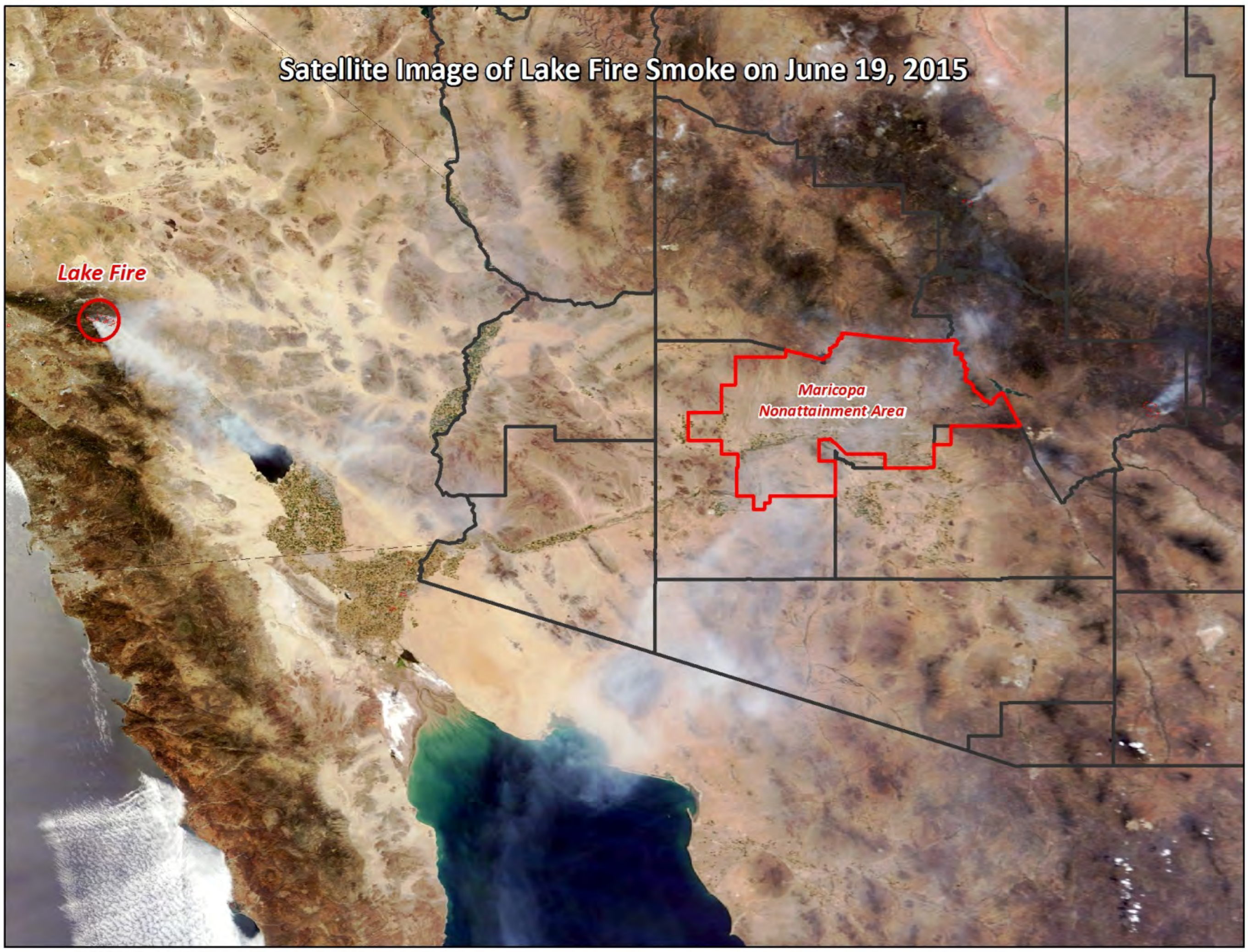

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I. INTRODUCTION

This documentation is being submitted to EPA to demonstrate that exceedances of the 2008 ozone standard at six monitors in or near the Maricopa eight-hour ozone nonattainment area on June 20, 2015 should be excluded from use in determinations of exceedances or violations of the ozone National Ambient Air Quality Standards (NAAQS) as exceptional events caused by a wildfire. Supplemental analysis of the June 20, 2015 exceedance at the Tonto National Monument monitor as it relates to the 2015 ozone standard is included in Appendix G. This documentation serves to meet the requirements of Clean Air Act Section 319(b) (Air quality monitoring data influenced by exceptional events); 40 CFR Section 50.14 (Treatment of air quality monitoring data influenced by exceptional events); and EPA's November 2015 draft *Guidance on the Preparation of Exceptional Events Demonstrations for Wildfire Events that May Influence Ozone Concentrations* (Wildfire Guidance). Additionally, EPA is currently in the process of revising the requirements of 40 CFR Section 50.14. This documentation is structured in such a way as to meet both the existing requirements in 40 CFR Section 50.14 and the proposed revisions to 40 CFR Section 50.14 that EPA plans to finalize in late 2016.

Summary of the Exceptional Event

On June 17, 2015, a large, human-caused wildfire (labeled as the Lake Fire) started in the San Bernardino National Forest in southeastern California. The fire burned approximately 31,359 acres and was 98% contained as of July 9, 2015, and completely contained as of August 1, 2015. The fire grew to approximately 14,968 acres (48% of the fire) in the first three days of the fire (June 17-19, 2015). Prevailing winds transported significant smoke, ozone and ozone precursor emissions from the Lake Fire into Arizona over the period of June 18 – June 20, 2015. These transported emissions caused exceedances of the 2008 ozone standard (0.075 ppm) at six monitors (Apache Junction, Blue Point, Falcon Field, Mesa, Pinnacle Peak, and Tonto National Monument) in or very near the Maricopa 8-hour ozone nonattainment area on June 20, 2015 as listed in Table 1–1. Satellite photos, smoke maps, back trajectories, elevated ozone concentrations across northern and central Arizona, and unusual NO_2 and $PM_{2.5}$ concentrations indicate that ozone and/or ozone precursor emissions from the Lake Fire were transported to the exceeding monitors and confirm a clear causal relationship between the exceeding monitors and the Lake Fire. Regression analyses provide additional evidence that the monitors affected by the ozone and ozone precursor emissions from the Lake Fire would not have normally exceeded the 2008 ozone standard under the meteorological conditions present in the nonattainment area on June 20, 2015.

Table 1-1. Ozone Monitors Affected by the Lake Fire Exceptional Event.

Monitor Name	County	Operating Agency	Monitor ID	Exceeding Ozone Concentration
Apache Junction	Pinal	Pinal County Air Quality Control District	04-021-3001	0.078 ppm
Blue Point	Maricopa	Maricopa County Air Quality Department	04-013-9702	0.077 ppm
Falcon Field	Maricopa	Maricopa County Air Quality Department	04-013-1010	0.080 ppm
Mesa	Maricopa	Maricopa County Air Quality Department	04-013-1003	0.079 ppm
Pinnacle Peak	Maricopa	Maricopa County Air Quality Department	04-013-2005	0.078 ppm
Tonto Nat. Monument	Gila	Arizona Department of Environmental Quality	04-007-0010	0.079 ppm

Statutory and Regulatory Requirements

Clean Air Act Section 319(b) defines an exceptional event as an event that:

1. affects air quality;
2. is not reasonably controllable or preventable.;
3. is an event caused by human activity that is unlikely to recur at a particular location or a natural event; and
4. is determined by the Administrator through the process established in the regulations promulgated under paragraph (2) [Regulations]to be an exceptional event.

EPA regulations in 40 CFR Section 50.14(c)(3)(iv) states that in order to justify excluding air quality monitoring data as an exceptional event, evidence must be provided for the following elements:

A. The event satisfies the criteria set forth in 40 CFR Section 50.1(j) that:
   (1) the event affected air quality,
   (2) the event was not reasonably controllable or preventable, and
   (3) the event was caused by human activity unlikely to recur in a particular location or was a natural event;
B. There is a clear causal relationship between the measurement under consideration and the event that is claimed to have affected the air quality in the area;
C. The event is associated with a measured concentration in excess of normal historical fluctuations, including background; and
D. There would have been no exceedance or violation but for the event.

The EPA proposed revisions to 40 CFR Section 50.14(c)(3)(iv) require a demonstration to justify data exclusion that must include:

A. A narrative conceptual model that describes the event(s) causing the exceedance or violation and a discussion of how emissions from the event(s) led to the exceedance or violation at the affected monitor(s);
B. A demonstration that the event affected air quality in such a way that there exists a clear causal relationship between the specific event and the monitored exceedance or violation;
C. Analyses identified in Table 3 to § 50.14 comparing the claimed event-influenced concentration(s) to concentrations at the same monitoring site at other times consistent with Table 3 to § 50.14 to support the requirement at paragraph (c)(3)(iv)(B) [clear causal relationship] of this section. The Administrator shall not require a State to prove a specific percentile point in the distribution of the data;
D. A demonstration that the event was both not reasonably controllable and not reasonably preventable; and
E. A demonstration that the event was a human activity that is unlikely to recur at a particular location or was a natural event

Details on how the statutory and regulatory requirements are addressed in this documentation is presented in the bulleted list below:

- Section II of this assessment includes a conceptual model that describes the genesis and location of the wildfire and how ozone and ozone precursor emissions from the wildfire caused the ozone exceedances on June 20, 2015 in the Maricopa nonattainment area.

- Section III provides a detailed body of evidence to support the clear causal relationship between the emissions from the wildfire and the ozone exceedances in the Maricopa nonattainment area and that the event affected air quality. This section includes an evaluation of the event to the tiered demonstration levels in EPA's Wildfire Guidance document, comparisons of event concentrations to historical ozone season concentrations, a discussion of the meteorology that allowed the transport of emissions from the fire to the exceeding monitors, a presentation of satellite photos, HYSPLIT trajectories and smoke maps showing that emissions from the wildfires reached the monitors, time-series maps showing elevated ozone concentrations across the state in response to the arrival of emissions from the wildfire, and elevated and unusual $PM_{2.5}$ and NO_2 concentrations in conjunction with the arrival of emissions from the wildfire. This section also includes a regression analysis that indicates that the affected monitors normally would not have exceeded the ozone standard under the meteorological parameters present on June 20, 2015. This regression analysis serves the dual purpose of providing additional evidence in support of the clear causal relationship between the wildfire and the exceedances, and as evidence that the monitors would not have exceeded but for the event (a requirement of the existing exceptional events regulations).

- Section IV presents evidence that the event was a natural event and that the event was neither reasonably controllable nor preventable.

- Section V includes a summary of the evidence presented in Sections II-IV.

Procedural Requirements

This section presents a review of the procedural requirements of the EER as required by 40 CFR Section 50.14. The procedural requirements include public notification that an event was occurring; placement of informational flags on data in EPA's Air Quality System (AQS); notification to EPA of the intent to flag through submission of initial event description; documentation that the public comment process was followed; and submittal of a demonstration supporting the exceptional events flag. Specific procedural requirements are presented below:

- Public notification that event was occurring, 40 CFR Section 50.14(c)(1)(i):

  The Arizona Department of Environmental Quality (ADEQ) issued an ensemble air quality forecast for the Greater Phoenix area on June 19, 2015 that discusses the presence of smoke from the Lake Fire in the area. At the time of the forecast, it was uncertain whether the smoke and emissions from the Lake Fire would affect ozone concentrations. ADEQ's ensemble forecast issued on June 21, 2015, confirmed that the emissions from the Lake Fire contributed to the ozone exceedances on June 20, 2015. The forecast products that were issued on June 19, 2015 and June 21, 2015 are included in Appendix A.

- Notify EPA of intent to exclude one or more measured exceedances by the placement of a flag in the appropriate field for the data record in AQS, 40 CFR Section 50.14(c)(2)(i):

  ADEQ and other operating agencies in Arizona submit data into EPA's AQS. When ADEQ and/or the operating agency have determined a potential exists that the monitor reading has been influenced by an exceptional event, a preliminary flag is submitted for the measurement in the AQS. The data are not official until they undergo more thorough quality assurance and quality control, leading to certification by May 1st of the year following the calendar year in which the data were collected (40 CFR Section 58.15(a)(2)). The presence of the flag can be confirmed in AQS. The following monitors have been flagged as exceeding the 2008 ozone standard on June 20, 2015 as a result of the wildfire exceptional event:

Apache Junction, (04-021-3001); Blue Point, (04-013-9702); Falcon Field, (04-013-1010); Mesa, (04-013-1003); Pinnacle Peak, (04-013-2005): and Tonto National Monument, (04-007-0010)

Additionally, EPA's proposed revisions to 40 CFR Section 50.14(c)(2)(i) require a state to engage in an Initial Notification of Potential Exceptional Event process. ADEQ began initial discussions with EPA about this event on February 29, 2016. From that date, frequent discussion continued with EPA on the development of documentation needed to support the event. ADEQ submitted formal initial notification of the June 20, 2015 ozone wildfire exceptional event to EPA Region IX on July 8, 2016. A copy of the initial notification form is included in Appendix F.

- Submittal of flagged data and initial event description to EPA by July 1 of calendar year following event, 40 CFR Section 50.14(c)(2)(iii):

  The ozone exceedances on June 20, 2015 caused by the wildfire event were flagged in AQS by April 2016. An initial description of the event is included with the flagged data. The April 2016 flagging date also complies with the exceptional event schedule requirements of the final EPA rule promulgating the 2015 ozone standard as reflected in Table 1 to 40 CFR 50.14(c)(2)(vi).

- Document that the public comment process was followed for event documentation, 40 CFR Section 50.14(c)(3)(v):

  ADEQ posted this assessment report on the ADEQ webpage and placed a hardcopy of the report in the ADEQ Records Management Center for public review. ADEQ opened a 30-day public comment period on August 16, 2016. A copy of the public notice certification, along with any comments received, will be submitted to EPA, consistent with the requirements of 40 CFR Section 50.14(c)(3)(v). See Appendix E for a copy of the affidavit of public notice.

- Submit demonstration supporting exceptional event flag, 40 CFR Section 50.14(c)(3):

  At the close of the comment period, and after ADEQ has had the opportunity to consider any comments submitted on this document, ADEQ will submit this document, the comments received, and ADEQ's responses to those comments to EPA Region IX headquarters in San Francisco, California. The deadline for the submittal of this demonstration package is October 1, 2016 in accordance with the schedule established with the issuance of the final 2015 ozone standard as reflected in Table 1 to 40 CFR Section 50.14(c)(2)(vi).

II. CONCEPTUAL MODEL

Typical Ozone Formation in the Maricopa Nonattainment Area

Overview

Ozone concentrations during the summer ozone season in the Maricopa eight-hour ozone nonattainment area are influenced by several factors including: westerly transport of upwind pollutants; a favorable synoptic weather pattern featuring high pressure over the northeastern portion of the state, a low pressure center in the southwest portion, and local emissions that are coincident with valley-wide stagnant and weak winds. The spatial distribution of high ozone concentrations depends on a diurnal valley breeze and directional change in winds induced by surrounding topography. Examination of the entire summer season shows the strong influence meteorological variability on ozone formation in the nonattainment area. As such, several meteorological regimes may result in an ozone exceedance. A map depicting the location of ozone monitors in the Maricopa eight-hour ozone nonattainment area is shown in Figure 2–1.

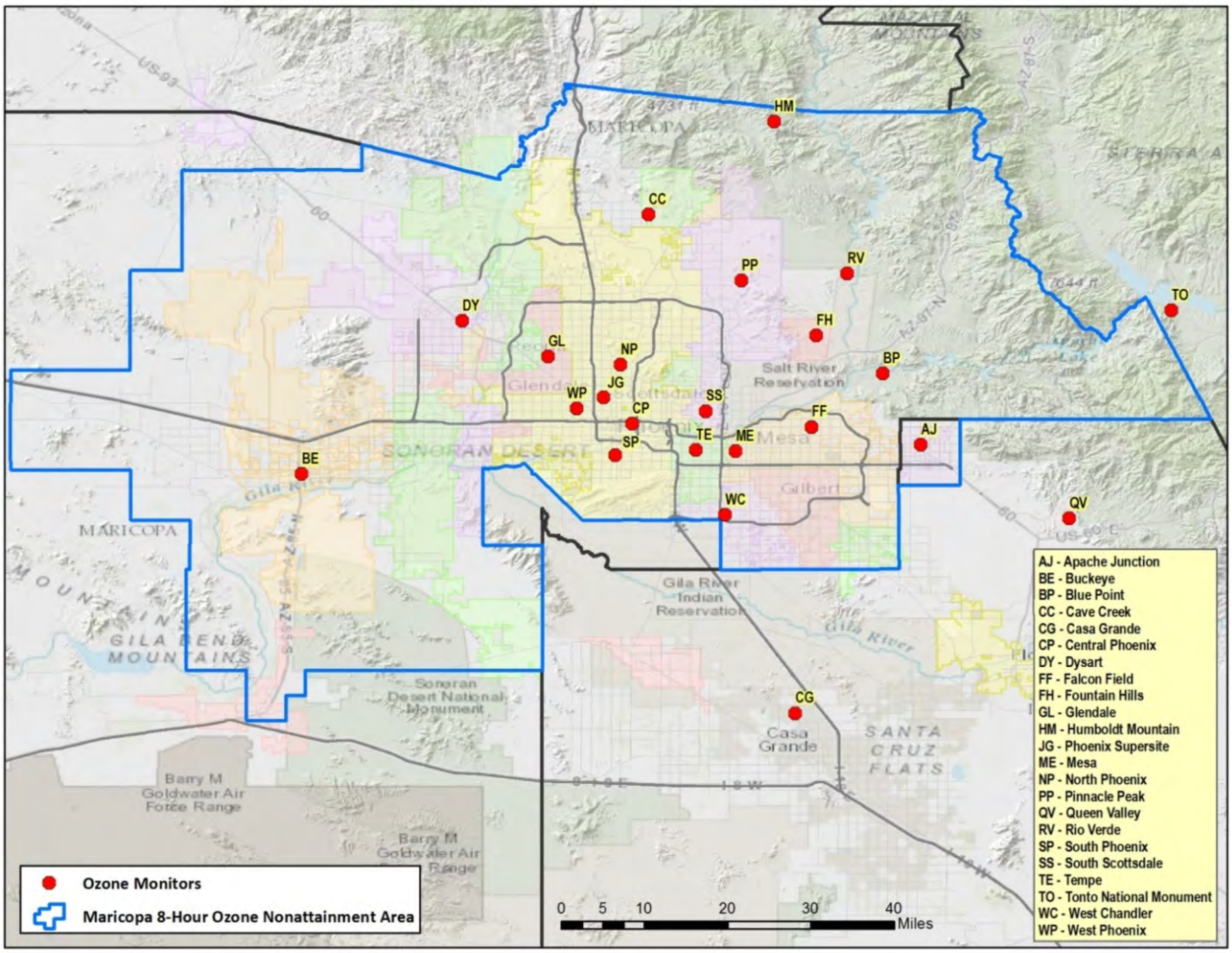

Figure 2-1. Maricopa eight-hour nonattainment area and ozone monitoring stations (monitors on tribal lands excluded).

The Phoenix metropolitan area includes several major cities and is the core of the nonattainment area. Networks of freeways and arterial roads, and several significant point sources, exist in the urban core. The edges of the nonattainment area are considered suburban or rural and monitoring sites in these zones are typically in more remote or mountainous locations. Ozone can advect downwind of the urban core to surrounding rural and suburban sites and these regions can have different profiles than those in the urban core. The coupling of the urban and downwind sites depends greatly on how the daily weather conditions interact with local emissions.

The photochemical reaction processes are essential for ozone formation. The desert Southwest yields sufficient solar radiation that promotes the efficient photochemical reactions of nitrogen oxides (NO_x) and volatile organic carbons (VOC) to form ground level ozone. Biogenic emissions are the largest VOC source, mostly formed in the Tonto National Forest located in the northeast portion of the nonattainment area and in agricultural areas. These emissions mix with urban anthropogenic VOC sources. The largest source of NO_x is motor vehicle exhaust, but point sources such as electric generating units are also important NO_x emission sources.

Transported ozone (international, interstate, stratospheric) can also influence local ozone levels, especially in the late spring and early summer when the transport pathways are conducive to elevated ozone. The nonattainment area is often downwind from source regions in Southern California and Northern Mexico. It is also aligned with the Rocky Mountains where early summer stratospheric ozone intrusions have been documented. Cold front storm systems associated with a southerly deviation of the late spring jet stream are conducive to these types of long range and vertical transport.

Under more localized conditions, most elevated ozone episodes occur under a distinct mesoscale meteorological pattern with a pronounced valley breeze or general stagnation. Many of the urban ozone monitors in the area are located within a basin surrounded by mountain ranges, and differential solar heating of surrounding topography often creates a thermal circulation known as the valley breeze. Under weak large scale summer weather patterns, local winds flow calmly to the southwest late at night and into morning and then strengthen towards the northeast in the afternoon hours. Although a variety of large scale weather patterns occur in the desert southwest, favorable patterns for elevated ozone often recur throughout the summer. These patterns create high temperatures, upper level winds from the south and/or west, sinking air from higher altitudes, and a sustained valley breeze circulation at the surface.

Each monitoring site within the nonattainment area exhibits a diurnal pattern in ozone levels, but the timing and magnitude depend on locations. Urban sites exhibit a more pronounced diurnal cycle in ozone, with the maximum occurring in late afternoon before sunset and the minimum just prior to sunrise. Ozone can be consumed by titration from locally generated NO_x in the urban core and also removed by dry deposition during night. In contrast, maximum ozone concentrations have been measured hours later at downwind rural sites. Most anthropogenic precursors are emitted from the urban core and follow a diurnal pattern related to traffic patterns that peak twice daily with the morning and evening rush hours. Anthropogenic emissions also vary by day of week, with most sources exhibiting lower emissions on the weekends due to fewer industrial, commercial and traffic activities. Naturally occurring VOC levels vary over the course of the ozone season, and biogenic emissions highly depend on meteorology (i.e. sunlight, temperature, and relative humidity).

Ozone Season Monthly Variations

Ozone concentrations vary by month in the ozone season, with historical exceedances of the 2008 ozone standard recorded in the months of April through September. Table 2–1 provides a month-by-month analysis of the number of ozone exceedance days (days with at least one exceeding monitor, relative to the 2008 ozone standard) per month in the Maricopa nonattainment area. Historically, a small percentage of exceedance days occurred in April and September, while more than 90% of the exceedance days occurred in May through August.

Table 2-1. Ozone Exceedance Days (2008 Standard) by Month in the Maricopa Eight-Hour Ozone Nonattainment Area.

Month	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
April	4	0	0	2	1	0	0	2	0	0	0	9
May	8	7	5	2	1	2	2	10	3	1	0	41
June	12	17	4	8	1	5	9	3	3	4	6	72
July	12	12	5	7	1	0	2	3	4	3	0	49
August	4	6	6	3	0	0	4	10	2	0	2	37
September	1	0	1	0	0	3	1	0	1	3	0	10

On average, May has relatively lower temperatures, less sunlight and stronger ventilating westerly winds, all of which typically limit ozone production. But during this time transport from Southern California and Mexico can be enhanced by cold fronts and stratospheric intrusions from late-spring low pressure systems. Cold fronts and associated westerly transport can recur several times before the monsoonal high pressure system begins to dominate in the region.

June is usually much warmer than May. Early in the month the air is dry prior to development of the southwestern monsoon pattern. Afternoons can be extremely hot (T > 110 °F) and dry (RH < 10%), and have the longest exposure to sunlight near the summer solstice. The majority of exceedance days have occurred historically in the month of June when local meteorological conditions (e.g., weak or stagnant winds) favor ozone production. By the end of the month, the monsoonal high pressure pattern begins to dominate.

July and August have extremely high daytime temperatures and are influenced much more by the regional monsoon pattern. A large scale upper level high pressure feature usually aligns over the Four Corners area and pumps moist, unstable air from the southeast. While the synoptic pattern can persist for several weeks, sudden changes in mesoscale weather during this time make ozone formation more complicated. Under monsoonal steering winds, small scale thunderstorms thrive under these favorable dynamics. Days are typically more humid and can exhibit short lived severe weather (intense rain, strong winds and windblown dust). The high pressure often controls the local flow in between thunderstorm events. Stagnant winds can last long enough to trap pollutants and create the highest ozone of the season. Additionally, peak biogenic VOC emissions occur in August that may enhance ozone formation.

Wildfire Description

The Lake Fire, located in the San Bernardino National Forest in southeastern California, began on June 17, 2015, as a human-caused wildfire that is still under investigation. The fire started out as an 87-acre fire on June 17, 2015 which rapidly grew to 6,080 acres on June 18, 2015, and 14,968 acres on June 19, 2015. It is the combined emissions of ozone and ozone precursor emissions on June 17-19, 2015 that resulted in the ozone exceedances on June 20, 2015 in the Maricopa nonattainment area. Figures 2–2 through 2–5 show the growth in the fire perimeter on June 17-20, 2015.

The fire ultimately burned 31,359 acres and was 98% contained by July 9, 2015, and fully contained by August 1, 2015. The fire burned through a combination of timber, brush and grass. A map of the fire area as of July 5-7, 2015 is included in Figure 2–6. A detailed description of the Lake Fire can be obtained here: http://inciweb.nwcg.gov/incident/4302/.

Figure 2–7 contains a map of the all fires actively burning in Arizona, southeastern California and northern Mexico on June 20, 2015, including the Lake Fire. The location of these fires was obtained at http://www.airfire.org/data/bluesky-daily/. The small fires burning southwest of Yuma (estimated to be approximately 100 acres each) in Mexico may have also contributed some ozone and ozone precursor emissions that were transported to the nonattainment area, but are minimal compared to the emissions from the Lake Fire. The larger fires burning east and north of the nonattainment area (e.g., Kearney Fire) appear to have minimal impact on the nonattainment area as emissions from these fires were blown north and east on prevailing winds. Figure 2–8 provides a satellite image of the Lake Fire smoke transporting across Arizona and the Maricopa nonattainment area on June 19, 2015.

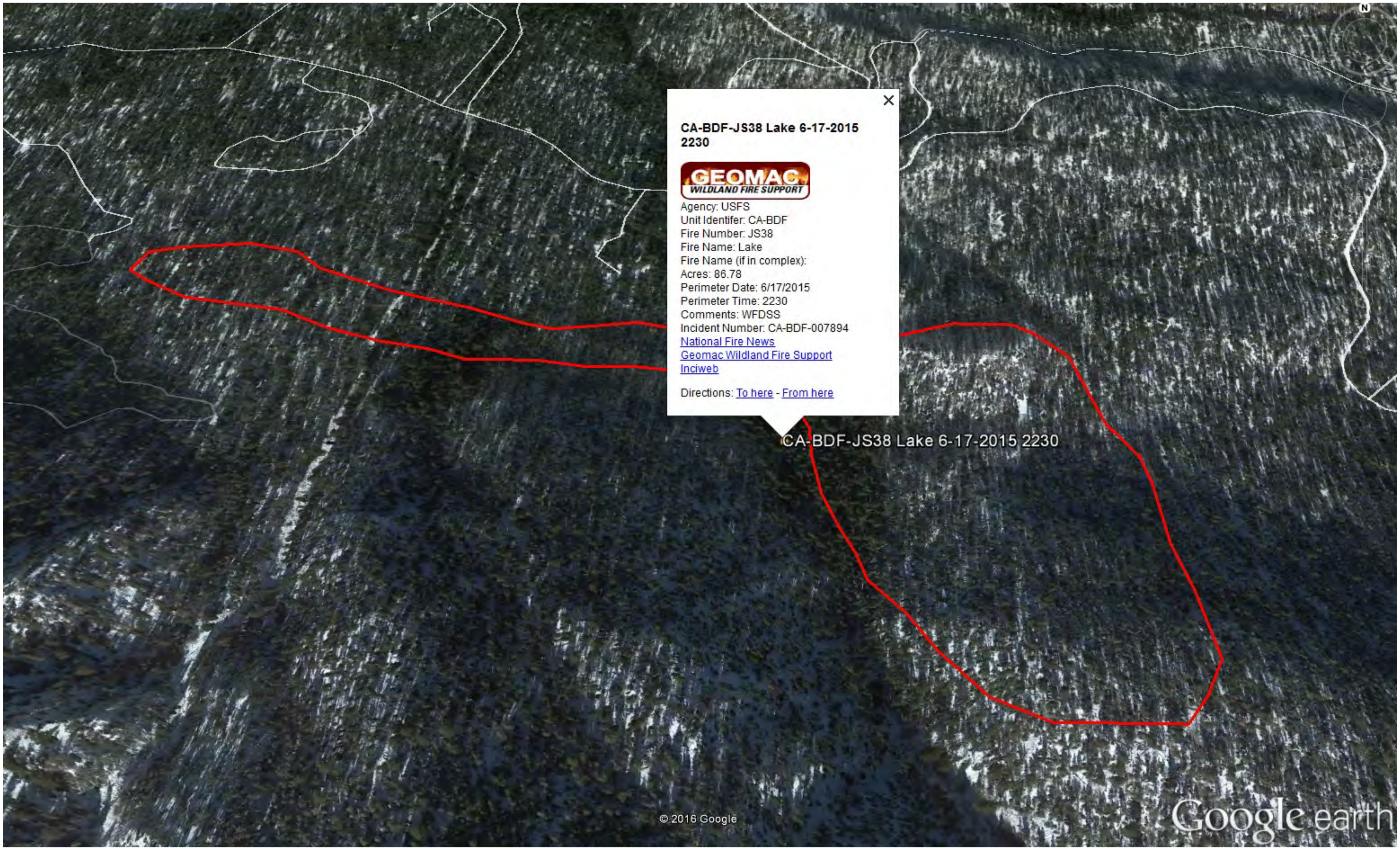

Figure 2-2. Lake Fire perimeter on June 17, 2015 (87 acres).

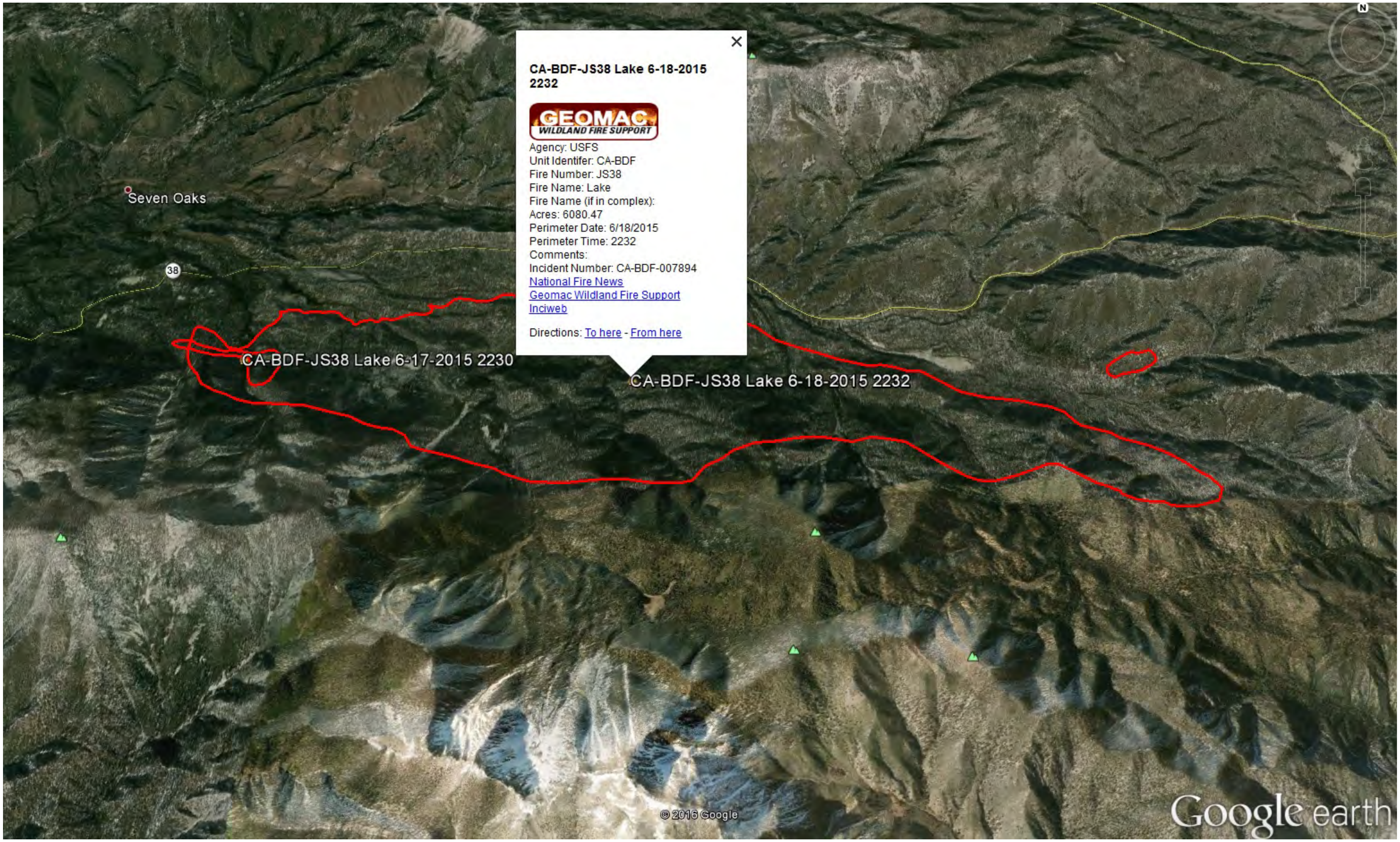

Figure 2-3. Lake Fire perimeter on June 18, 2015 (6,080 acres).

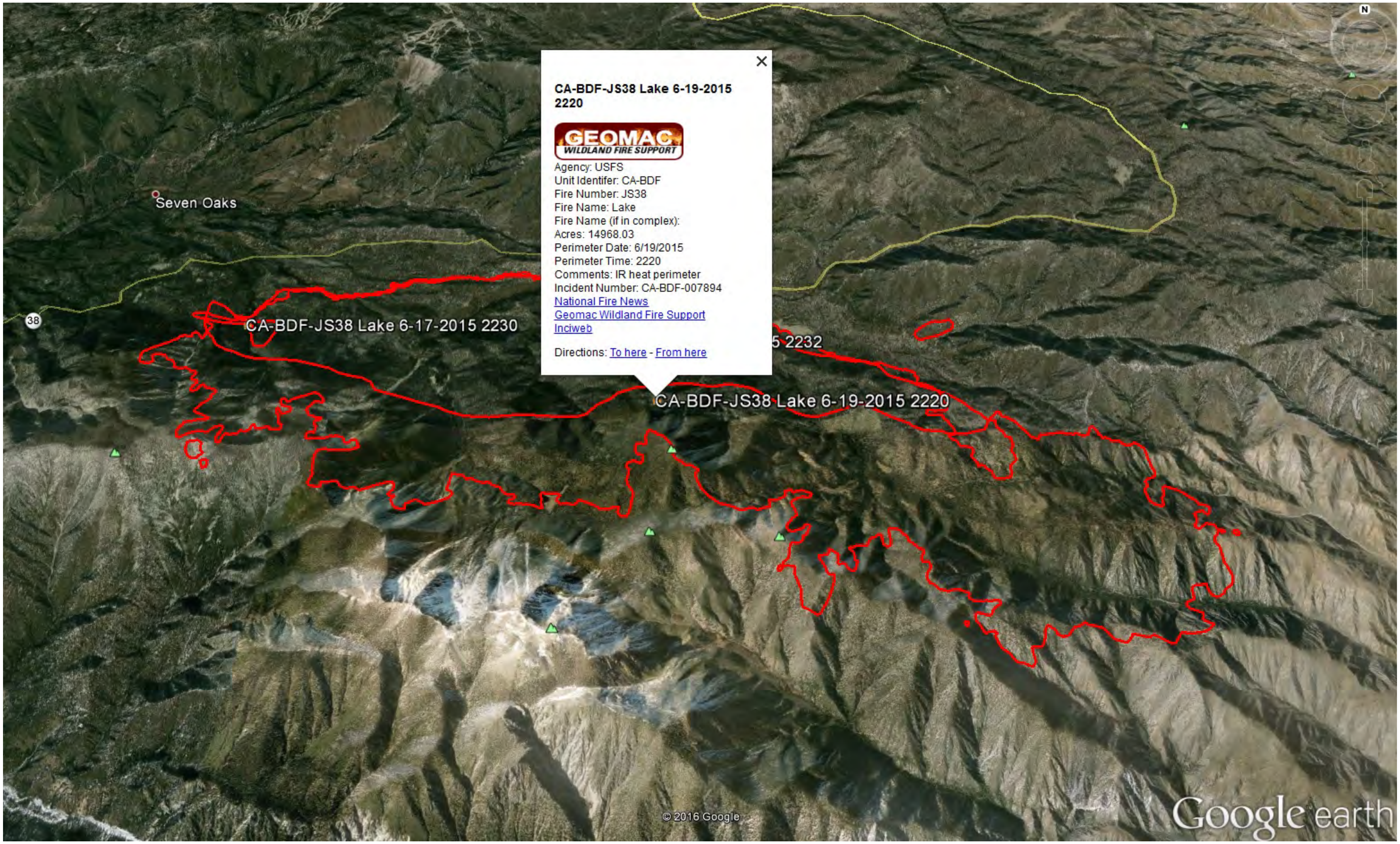

Figure 2-4. Lake Fire perimeter on June 19, 2015 (14,968 acres).

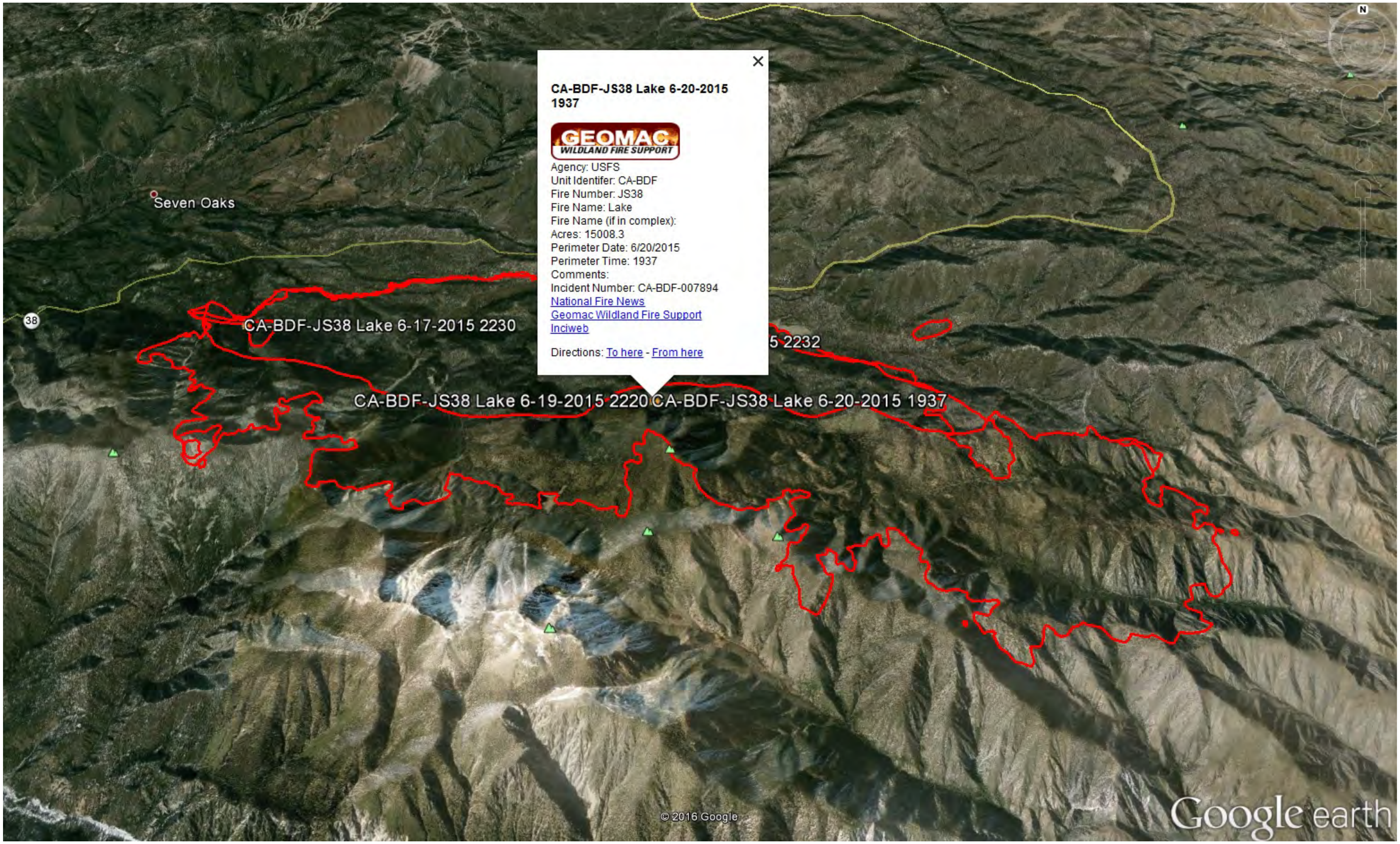

Figure 2-5. Lake Fire perimeter on June 20, 2015 (15,008 acres).

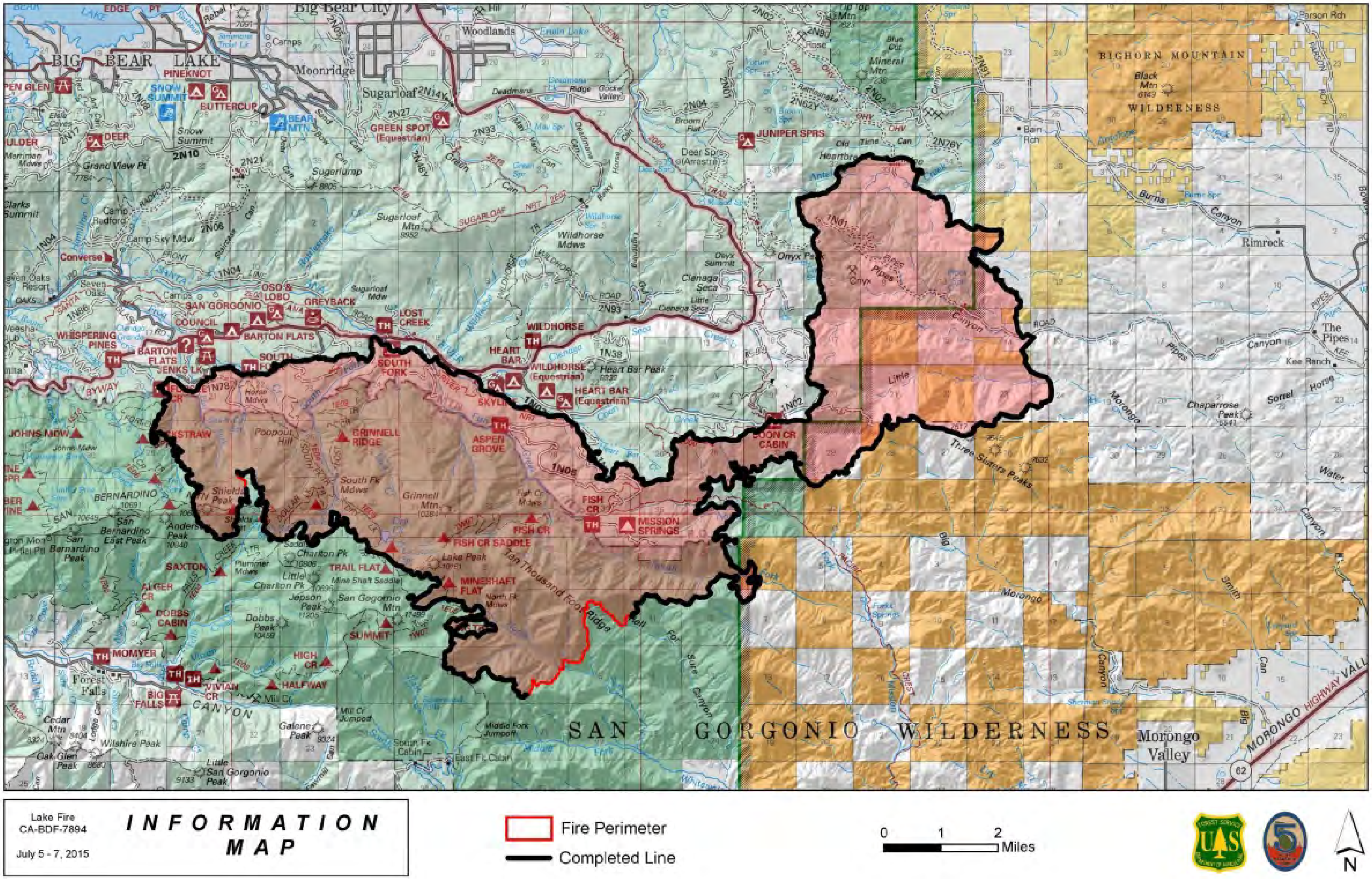

Figure 2-6. Map of the Lake Fire as of July 5-7, 2015.

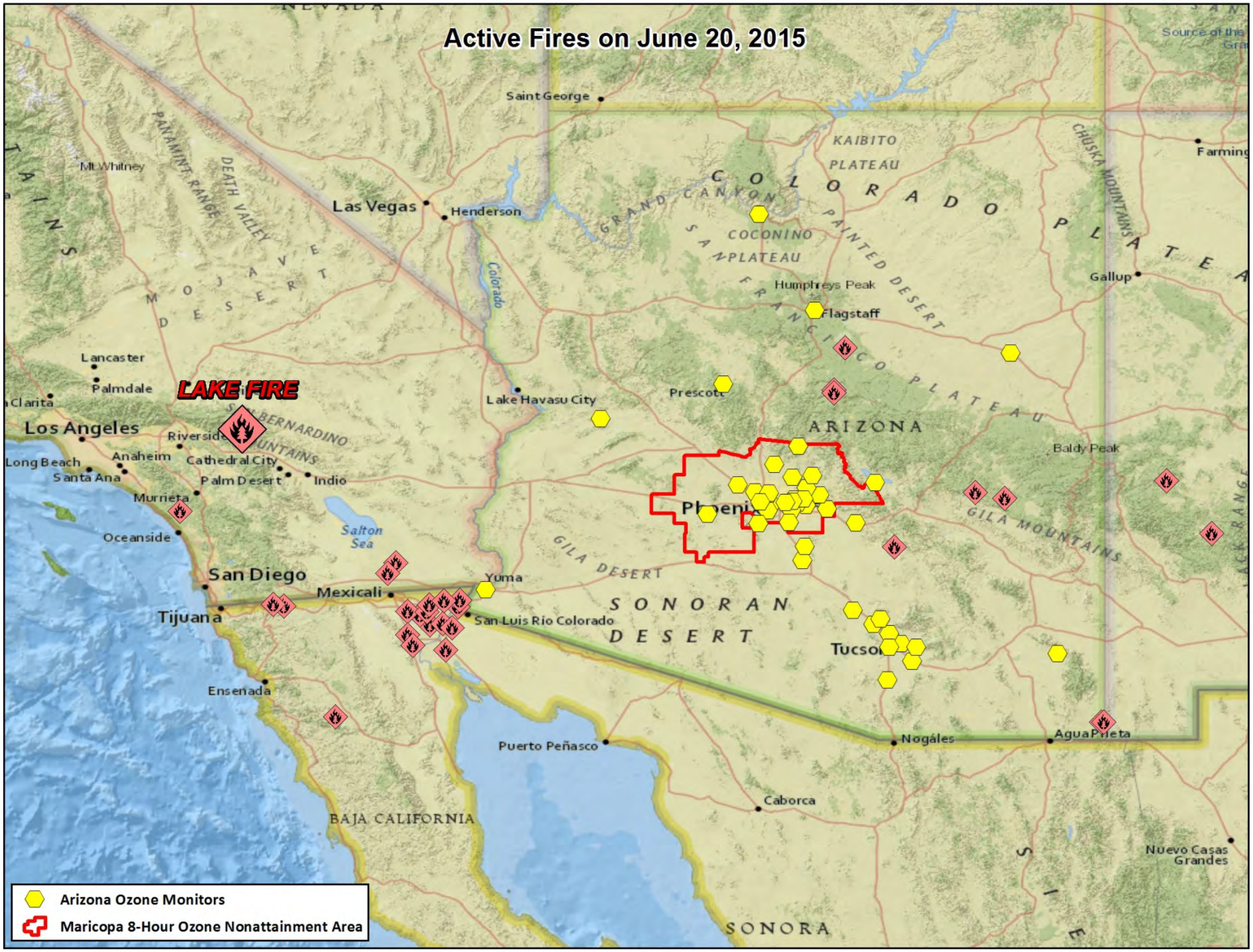

Figure 2-7. Active wildfires on June 20, 2015 in Arizona, southeastern California and northern Mexico.

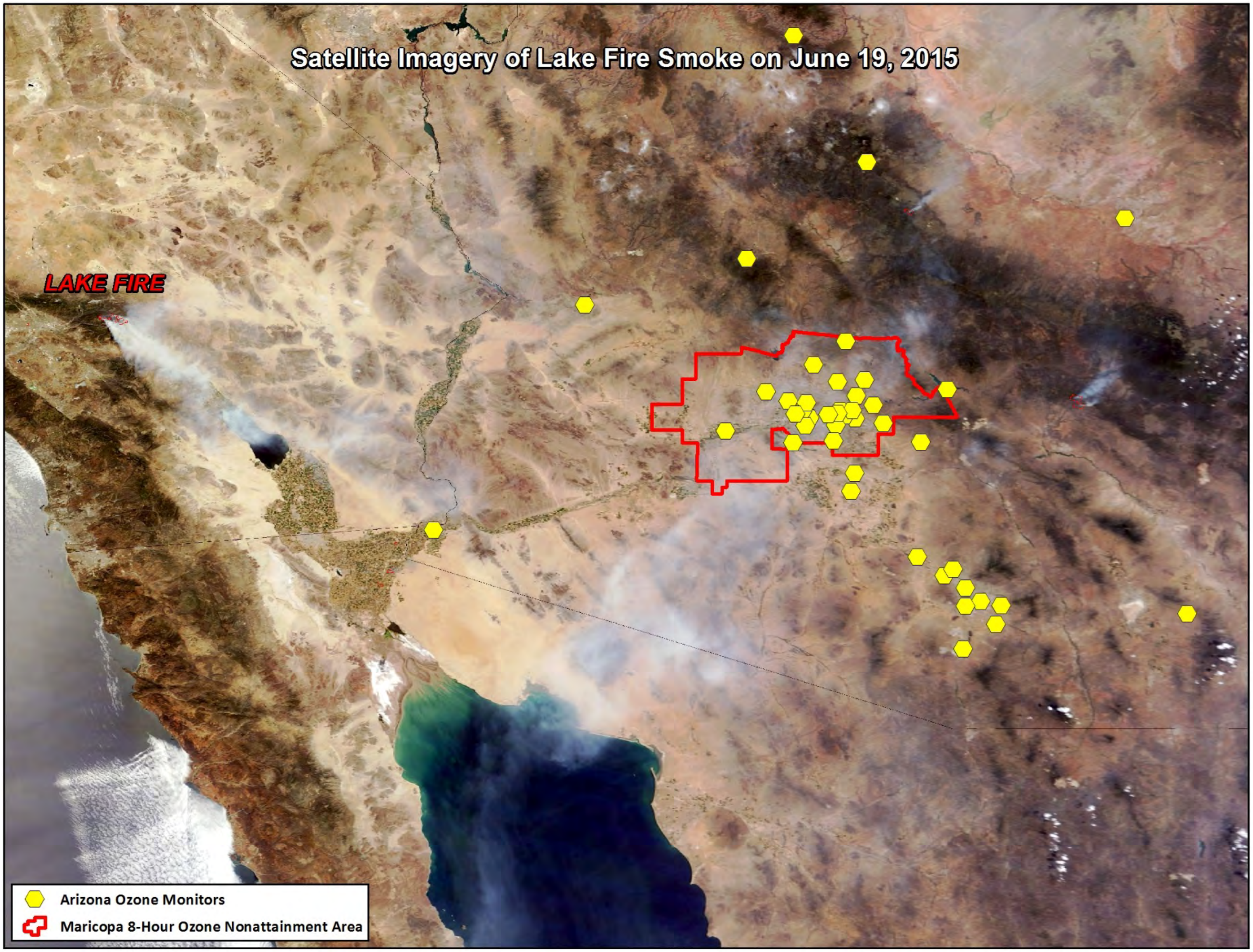

Figure 2-8. Satellite imagery of Lake Fire smoke on June 19, 2015.

<u>Ozone Formation in the Maricopa Nonattainment Area due to the Wildfire Event</u>

From June 17, 2015 to June 19, 2015, the human-caused Lake Fire wildland wildfire in the San Bernardino National Forest in southeastern California produced ozone and ozone precursor emissions that were transported to the Maricopa 8-hour ozone nonattainment area, causing six monitors to exceed the 2008 ozone standard (0.075 ppm) on June 20, 2015. The fire's rapid growth (perimeters of 87 acres on June 17; 6,080 acres on June 18; and 14,968 acres on June 19, 2015) quickly produced large amounts of smoke, ozone and ozone precursor emissions within the first three days of the fire. Smoke from the Lake Fire is visible across substantial portions of Arizona and the nonattainment area on June 18-20, 2015 in satellite photos and NOAA HMS satellite-derived smoke maps, indicating the transport of smoke (and associated ozone and ozone precursor emissions) from the fire into Arizona and the nonattainment area.

As the ozone and ozone precursor emissions from the fire transported west to east across Arizona on prevailing winds, ozone concentrations elevated across northern and central Arizona with the advancing plume, highlighted by the exceedance of the ozone standard at the Yuma monitor on June 19, 2015 and the near exceedance of the standard at two rural monitors on June 19, 2015 (Alamo Lake and Grand Canyon monitors). Elevated concentrations of $PM_{2.5}$ are recorded at both the Yuma and Alamo Lake monitors on June 18, 2015 and June 19, 2015 indicating the presence of smoke at these monitors. As the plume reaches the nonattainment area on the afternoon/evening of June 19, 2015 the plume carries ozone and ozone precursors from the Lake Fire, as well as ozone that was created when the fire emissions interacted with urban emissions in Yuma. This transported ozone and ozone precursor emissions interact with the normal, seasonal emissions in the nonattainment area, causing exceedances at six monitors on June 20, 2015. The diurnal pattern of ozone concentrations on June 20, 2015 indicate the ozone plume starting out in the central portion of the nonattainment area in the morning/afternoon, and then moving slowly east and out of the nonattainment area on valley breezes into the afternoon and early evening. Unusually high concentrations of NO_2 on June 20, 2015 (a Saturday) in the nonattainment area provide evidence of the presence of an additional source of ozone or ozone precursor emissions and vary from the pattern seen during non-event exceedances of the ozone standard earlier in the month on June 12, 2015.

A regression analysis was performed to determine what the ozone concentration would have been at the exceeding monitors in the absence of Lake Fire ozone and ozone precursor emissions. Six years (2010-2015) of June meteorological and ozone concentration data in the nonattainment area were analyzed to develop a statistical relationship between meteorological parameters and ozone concentrations on non-event days. Results of this regression analysis find that the monitors affected by the ozone and ozone precursor emissions from the Lake Fire would not have normally exceeded the 2008 ozone standard under the meteorological conditions that existed on June 20, 2015.

Ozone Monitoring Data

Table 2–2 contains the maximum daily eight-hour average ozone concentration for the Maricopa nonattainment ozone monitors from June 13-27, 2015. Figures 2–9 and 2–10 provide a graph of the same values for the exceeding monitors and all nonattainment areas monitors, respectively. Figure 2–11 provides the diurnal profile of the exceeding monitors on June 20, 2015.

Table 2-2. Maximum Daily Eight-Hour Ozone Concentrations (ppm) at Maricopa Nonattainment Area Monitors on June 13-27, 2015.

Monitor	June 13	June 14	June 15	June 16	June 17	June 18	June 19	June 20	June 21	June 22	June 23	June 24	June 25	June 26	June 27
Apache Junction	0.069	0.067	0.068	0.073	0.067	0.069	0.065	**0.078**	0.059	0.067	0.069	0.059	0.065	0.067	0.065
Blue Point	0.064	0.062	0.067	0.069	0.065	0.066	0.067	**0.077**	0.052	0.065	0.063	0.058	0.061	0.064	0.056
Buckeye	0.058	0.052	0.052	0.049	0.051	0.052	0.056	0.054	0.039	0.045	0.043	0.048	0.036	0.038	0.044
Cave Creek	0.066	0.059	0.061	0.061	0.063	0.064	0.068	0.069	0.047	0.060	0.055	0.062	0.057	0.050	0.053
Central Phoenix	0.066	0.063	0.063	0.071	0.063	0.063	0.065	0.068	0.057	0.062	0.056	0.059	0.053	0.050	0.058
Dysart	0.063	0.056	0.058	0.058	0.062	0.060	0.061	0.062	0.044	0.055	0.053	0.056	0.049	0.044	0.05
Falcon Field	0.07	0.068	0.070	0.065	0.067	0.069	0.068	**0.080**	0.059	0.070	0.066	0.063	0.065	0.064	0.065
Fountain Hills	0.068	0.061	0.063	0.064	0.062	0.063	0.068	0.073	0.053	0.065	0.062	0.061	0.058	0.056	0.055
Glendale	0.064	0.059	0.051	0.057	0.060	0.058	0.066	0.064	0.046	0.060	0.053	0.050	0.041	0.044	0.048
Humboldt Mountain	0.063	0.059	0.062	0.062	0.062	0.059	0.069	0.073	0.050	0.062	0.056	0.063	0.057	0.051	0.055
JLG Supersite	0.069	0.067	0.068	0.073	0.066	0.069	0.066	0.068	0.054	0.064	0.058	0.061	0.052	0.048	0.056
Mesa	0.069	0.068	0.069	0.077	0.069	0.068	0.069	**0.079**	0.061	0.066	0.058	0.064	0.062	0.058	0.065
North Phoenix	0.071	0.068	0.071	0.070	0.068	0.070	0.071	0.073	0.055	0.070	0.062	0.063	0.055	0.050	0.056
Pinnacle Peak	0.073	0.066	0.070	0.068	0.068	0.070	0.074	**0.078**	0.056	0.067	0.064	0.068	0.067	0.059	0.059
Rio Verde	0.057	0.054	0.055	0.054	0.055	0.058	0.061	0.065	0.043	0.055	0.053	0.054	0.051	0.051	0.048
South Phoenix	0.066	0.061	0.063	0.073	0.065	0.063	0.065	0.067	0.058	0.059	0.055	0.061	0.049	0.047	0.054
South Scottsdale	0.065	0.063	0.066	0.064	0.059	0.060	0.059	0.070	0.053	0.063	0.056	0.058	0.055	0.049	0.054
Tonto Nat. Monument	0.065	0.057	0.068	0.064	0.063	0.069	0.067	**0.079**	0.054						
West Chandler	0.064	0.063	0.066	0.072	0.062	0.067	0.063	0.069	0.057	0.061	0.063	0.062	0.057	0.052	0.057
West Phoenix	0.066	0.063	0.064	0.071	0.066	0.066	0.064	0.067	0.052	0.062	0.058	0.060	0.050	0.048	0.055

(Monitoring Data Notes: The Tonto National Monument monitor is located less than 2 miles outside of the eastern boundary of the Maricopa nonattainment area in Gila County. While not included in this demonstration, three ozone monitors in the Salt River Pima-Maricopa Indian Community exceeded on June 20, 2015 as a result of the Lake Fire, as well an exceedance at the Yuma monitor on June 19, 2015. The Tempe monitor was not operational during this event.)

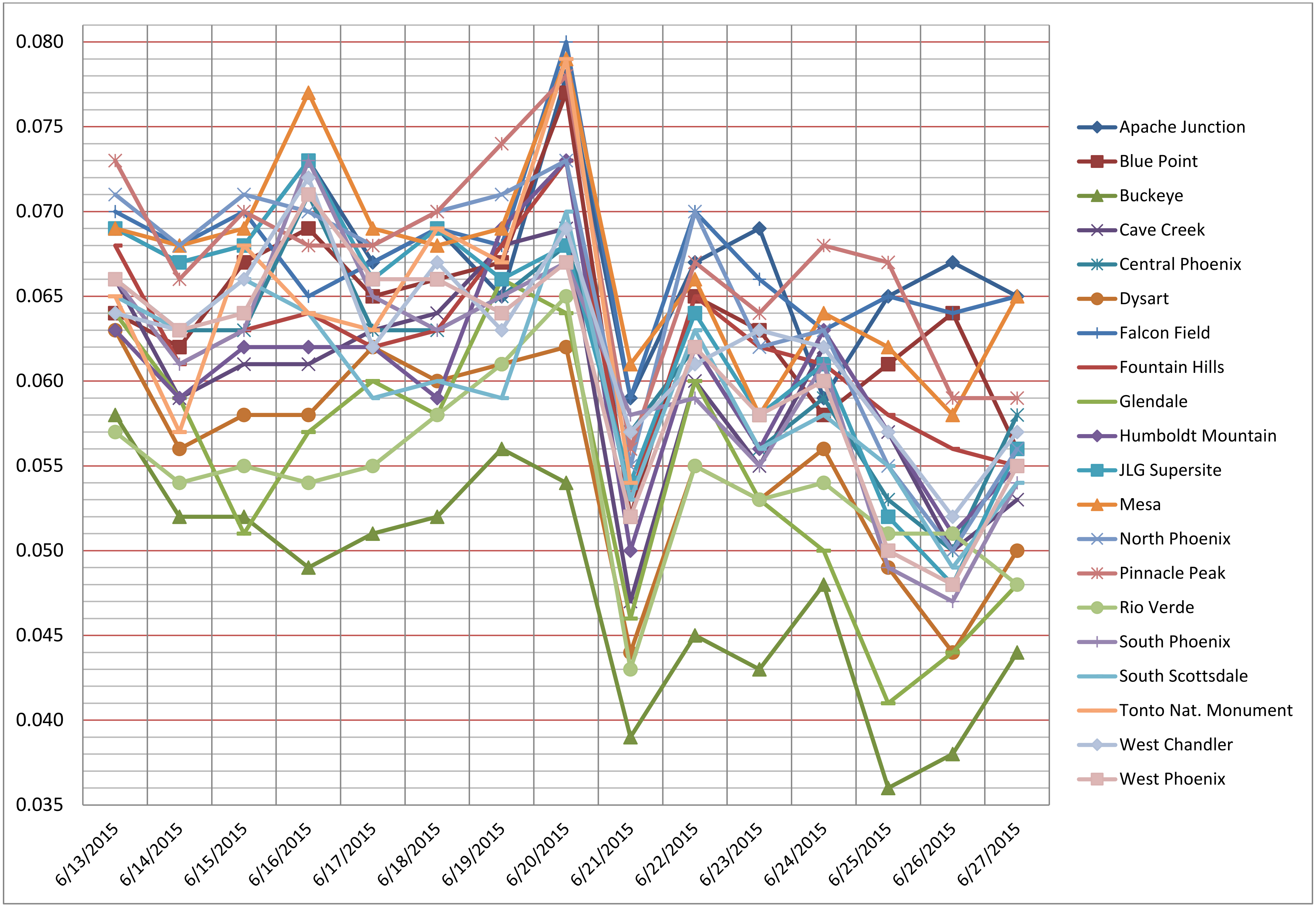

Figure 2-9. Maximum daily eight-hour ozone concentrations (ppm) at the nonattainment area monitors on June 13-27, 2015.

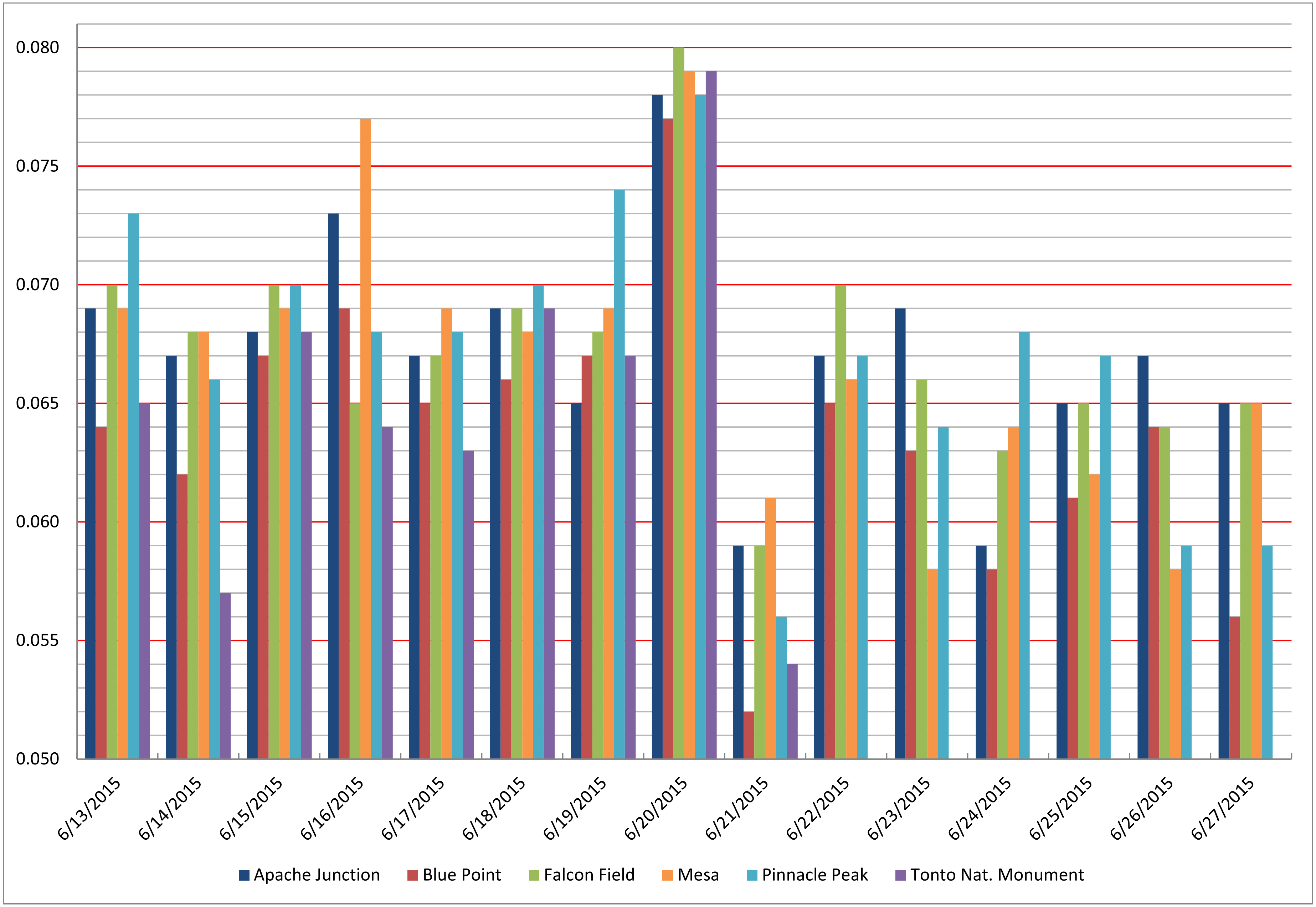

Figure 2-10. Maximum daily eight-hour ozone concentrations (ppm) at the exceeding monitors on June 13-27, 2015.

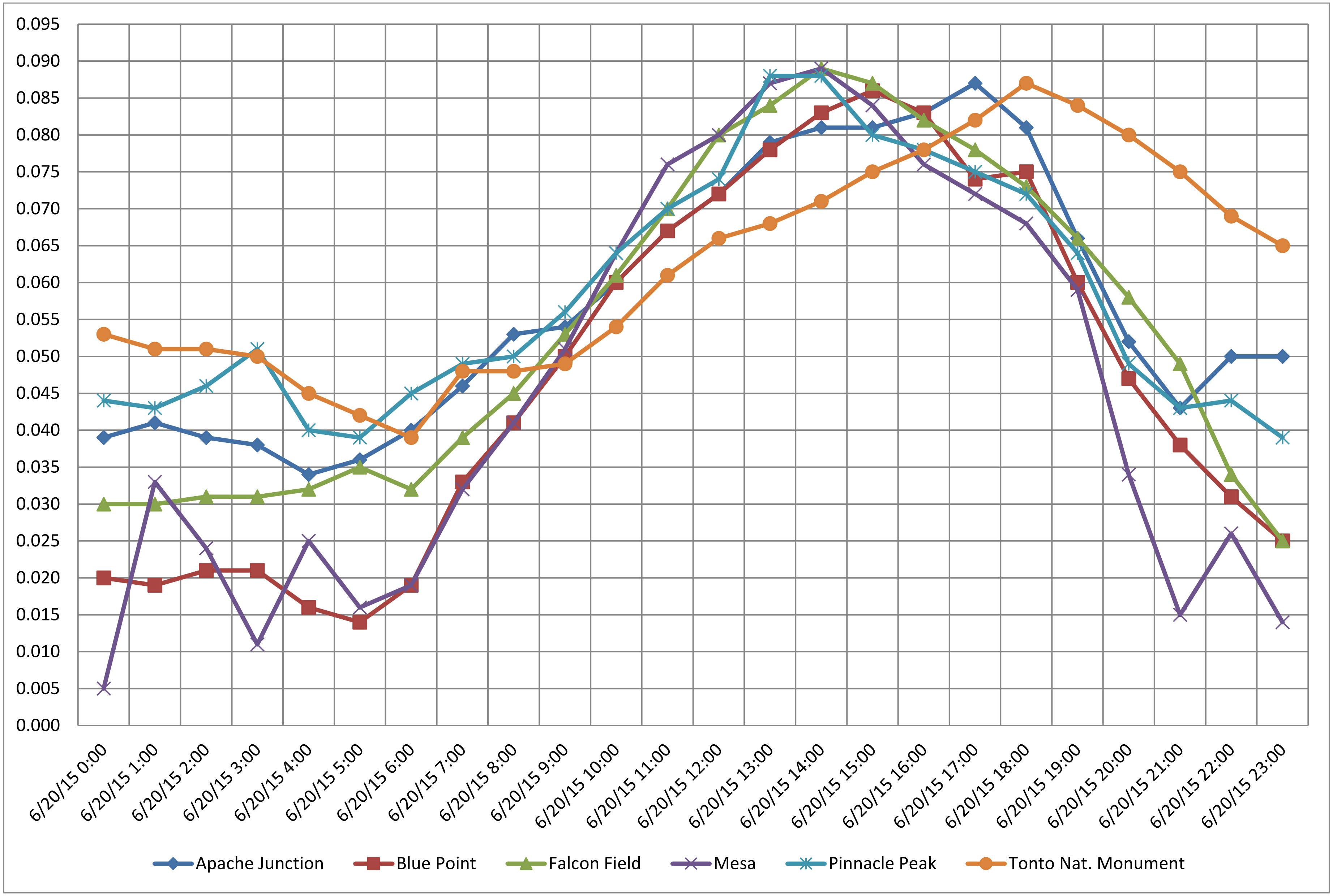

Figure 2-11. Diurnal profile of exceeding monitors on June 20, 2015.

III. CLEAR CAUSAL RELATIONSHIP

Introduction

This section of the documentation demonstrates provides several pieces of evidence that the wildfire affected air quality in such a way that a clear causal relationship between the wildfire and the monitored exceedances if apparent. EPA's November 2015 draft *Guidance on the Preparation of Exceptional Events Demonstrations for Wildfire Events that May Influence Ozone Concentrations* (Wildfire Guidance) states that "Air agencies should support the clear causal relationship with a comparison of the O_3 data requested for exclusion with historical concentrations at the monitor. In addition...a clear causal relationship is generally established by demonstrating that the fire's emissions were transported to the monitor, the fire's emissions affected the monitor, and, in some cases, a quantification of the level of impact of the fire's emissions on the monitored O_3 concentration." Demonstrations covering all of the elements of a clear causal relationship stated by EPA are presented in the sections below.

Comparison of Event Concentrations with Historical Concentrations

As part of the demonstration that air quality was affected by the wildfire event, and to begin to establish the clear causal relationship between the event and the exceedances, a comparison of the exceeding ozone concentrations on June 20, 2015 is compared to the historical, non-event ozone season concentrations. One of the comparisons recommended by EPA in the Wildfire Guidance is a comparison of the event concentration at the exceeding monitor to the 5-year historical ozone season concentrations at the same monitor. As the examples in the Guidance include the months of April-October as representative of the ozone season, the graphs below include historical ozone concentration data from the months of April through October.

The graphs of the 5-year historical ozone season concentrations for each of the exceeding monitors are included in Figures 3–1 through 3–6. Exceedances of the 2008 ozone standard are represented as red dots in the figures. While there is a possibility that some of the historical exceedances may have been impacted by wildfires, no other historical exceedance has been flagged as an exceptional event due to a wildfire. The 99^{th} percentile value for the 5-year, ozone season (April-October, 2011-2015) is also listed on each figure. All but one of the six exceeding monitors (Pinnacle Peak) had maximum daily eight-hour average ozone concentrations on June 20, 2015 that were at or above the 5-year, ozone season 99th percentile. For Pinnacle Peak, which had a concentration below the 99th percentile, the exceedance on June 20, 2015 was the third highest daily maximum 8-hour average ozone concentration recorded at Pinnacle Peak in 2015.

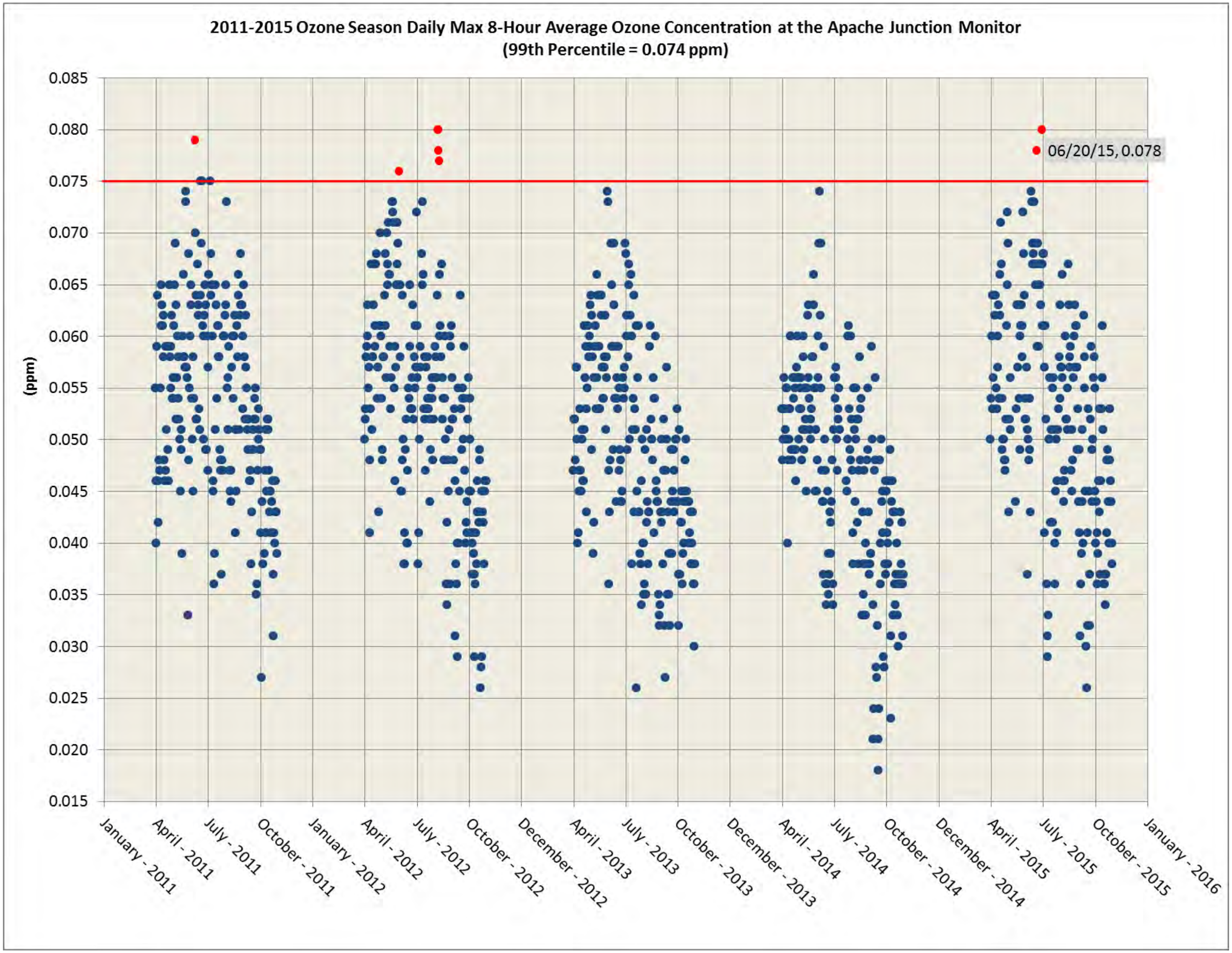

Figure 3-1. Plot of 5-year ozone season daily maximum 8-hour average concentrations at the Apache Junction monitor.

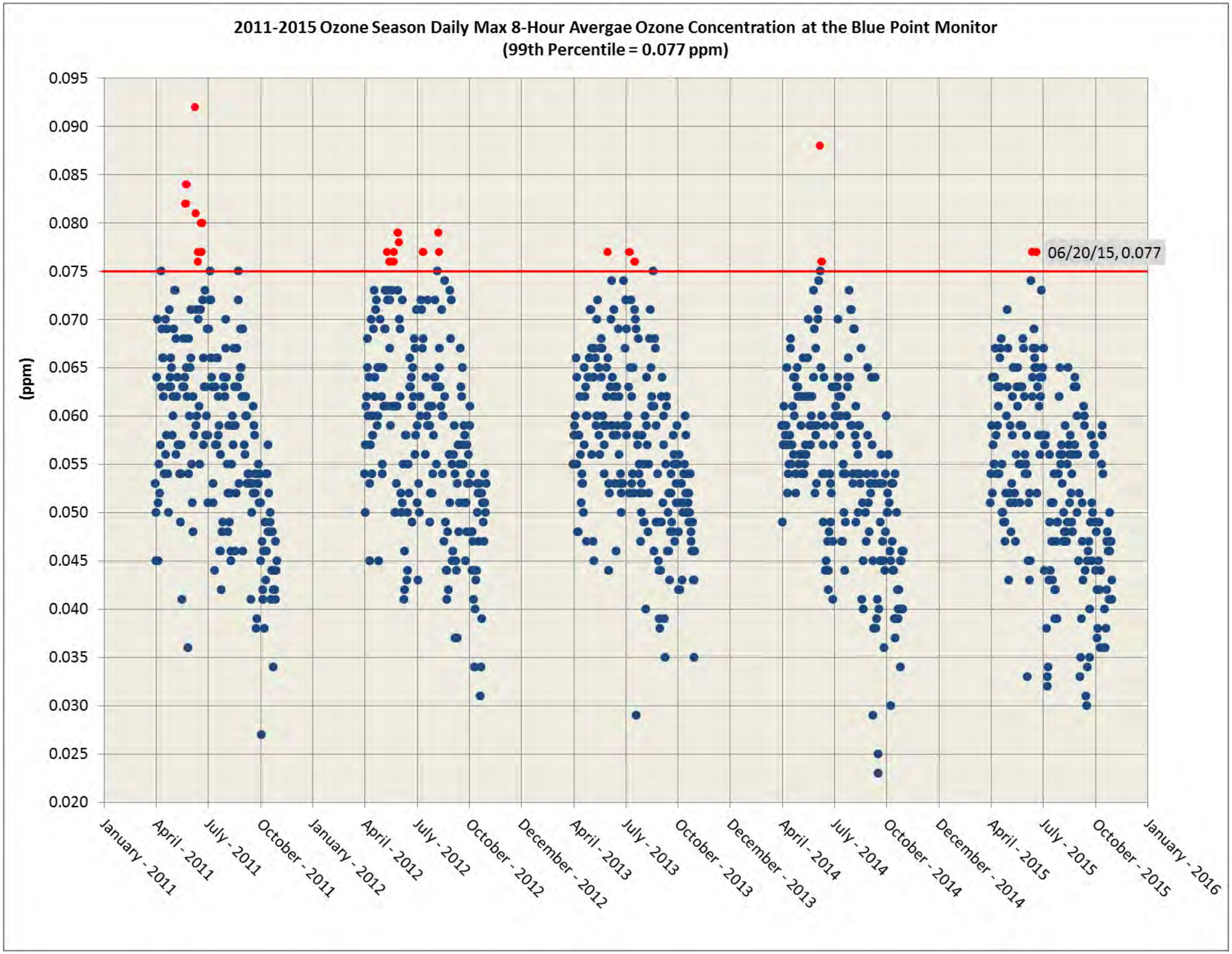

Figure 3-2. Plot of 5-year ozone season daily maximum 8-hour average concentrations at the Blue Point monitor.

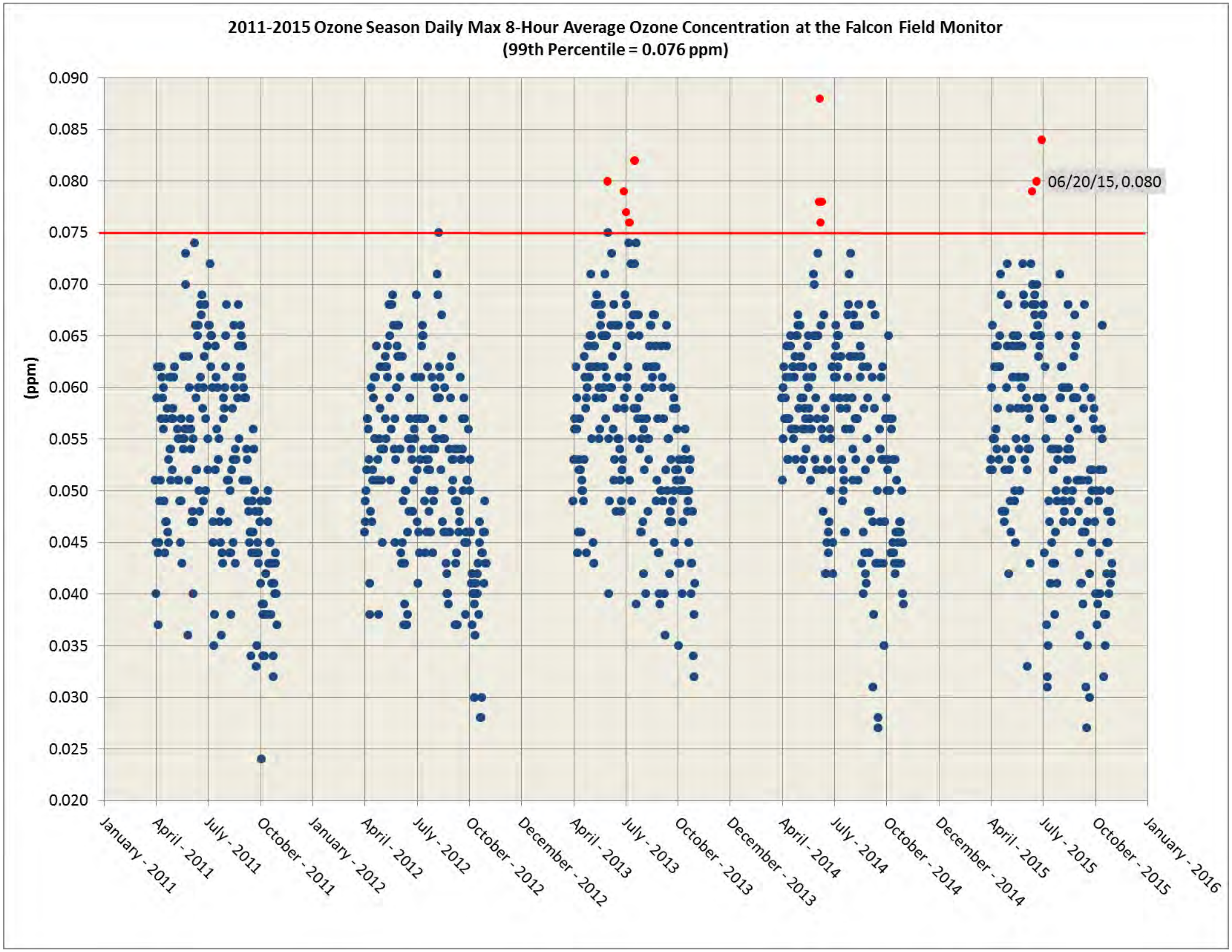

Figure 3-3. Plot of 5-year ozone season daily maximum 8-hour average concentrations at the Falcon Field monitor.

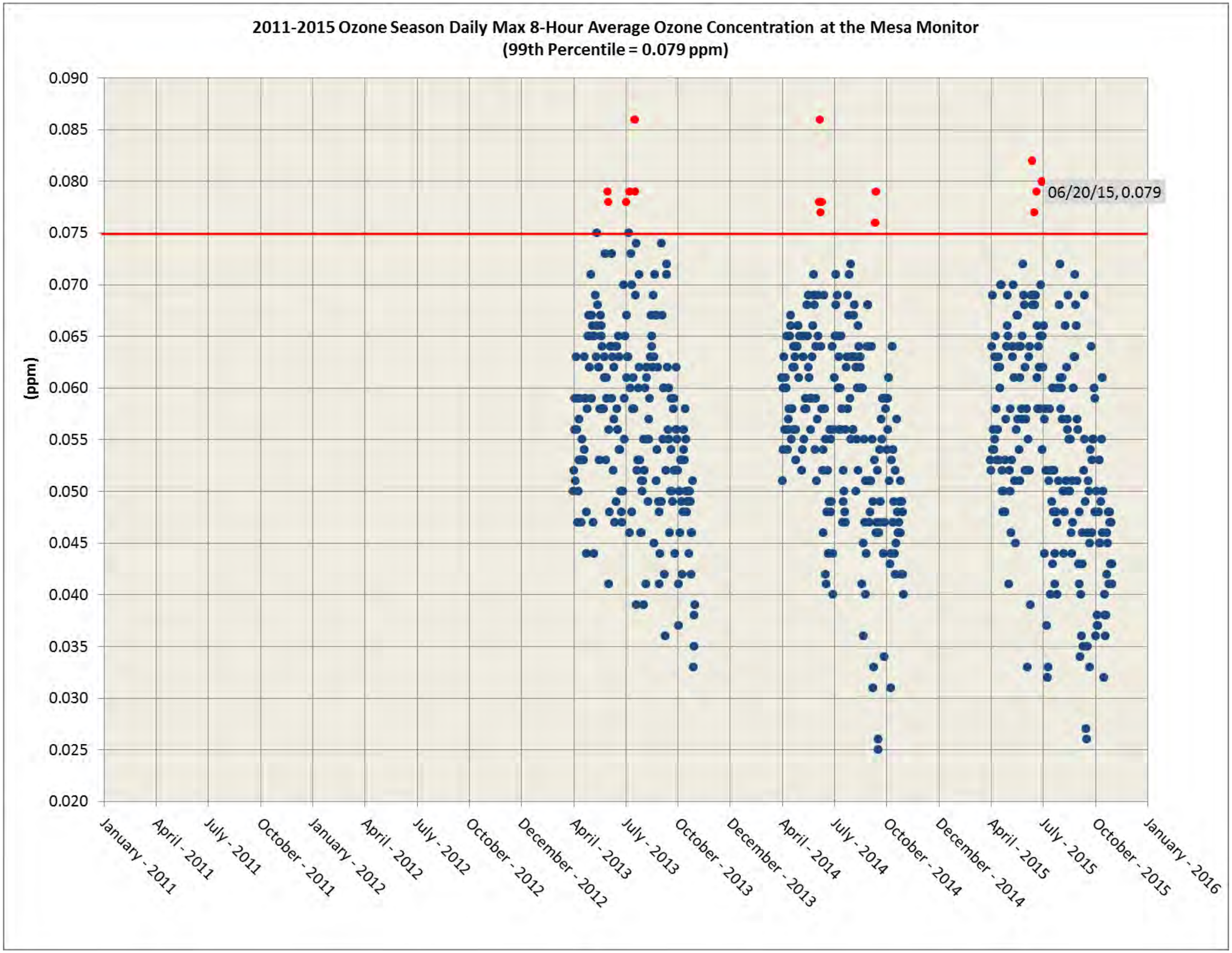

Figure 3-4. Plot of 5-year ozone season daily maximum 8-hour average concentrations at the Mesa monitor.

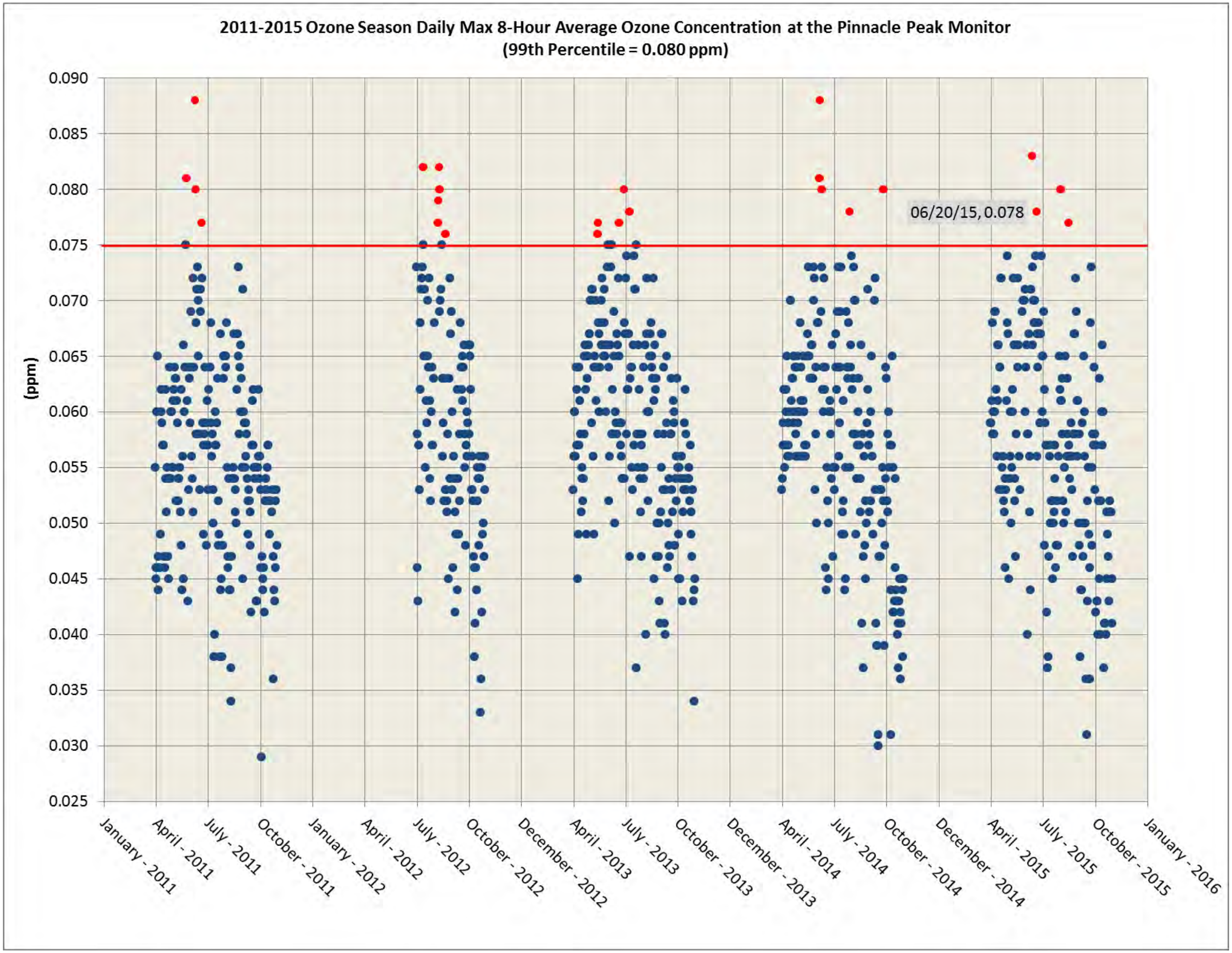

Figure 3-5. Plot of 5-year ozone season daily maximum 8-hour average concentrations at the Pinnacle Peak monitor.

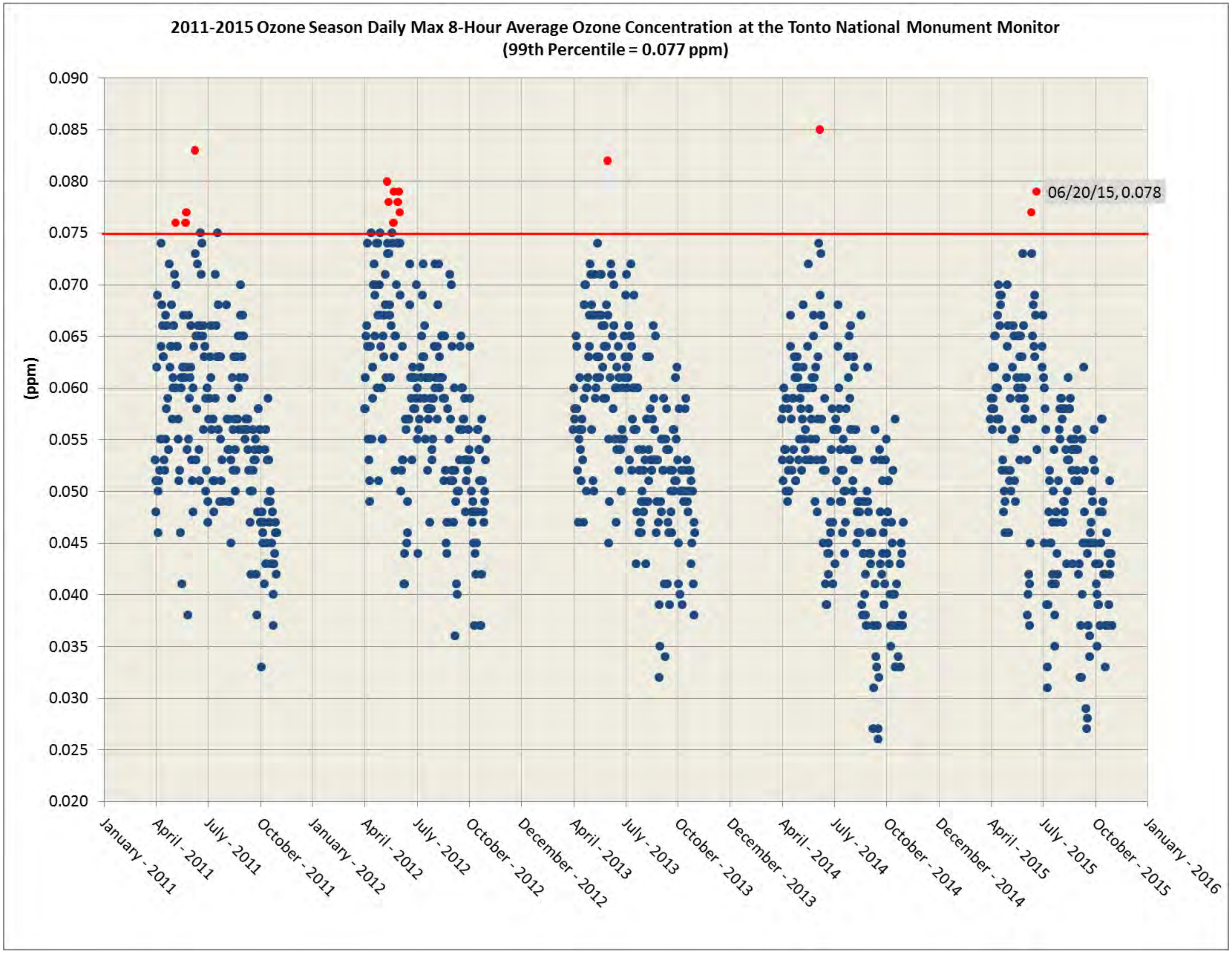

Figure 3-6. Plot of 5-year ozone season daily maximum 8-hour average concentrations at the Tonto National Monument monitor.

Tiered Approach

EPA's Wildfire Guidance establishes demonstration tiers for determining the level of evidence needed to document an exceptional event in conjunction with reviewing each demonstration on a case-by-case basis using a weight of the evidence approach. Three tiers are described in the Guidance:

- Tier 1 demonstrations are reserved for the clearest events, such as events where the wildfire is located in close proximity to a monitor or when the wildfire occurs during the time of year with typically low ozone concentrations. These demonstrations require the least amount of evidence and documentation.

- Tier 2 demonstrations are used when impacts from the wildfire are less clear, such as events when the concentrations are only a few parts per billion over the standard or events that occur during the ozone season when ozone concentrations may be high apart from the event contribution. Tier 2 demonstrations require more evidence than Tier 1 demonstrations.

- Tier 3 demonstrations are used when the relationship between the wildfire and the influenced ozone concentrations are the most complex. The level of documentation and evidence required is highest for Tier 3 demonstrations. The Guidance suggests discussing with EPA Regional Offices the appropriate level of evidence needed for a Tier 3 demonstration.

To help determine when a Tier 1, Tier 2, or Tier 3 demonstration is required, the Wildfire Guidance identified "key factors" that act as screening tool for selecting a suitable tier for a given event. According to the Guidance, the relationships of the event to the key factors identify which tier is most appropriate for the event and may help to inform the amount of information needed in higher tier demonstrations.

The key factor for a Tier 1 demonstration is the "[s]easonality and/or distinctive level of the monitored O_3 concentration". Tier 1 demonstrations are meant to apply to ozone exceedances that occur outside the ozone season or have concentrations that are at least 5-10 parts per billion higher than non-event related concentrations. Since the exceedances in this documentation occurred during the middle of the ozone season and were not significantly higher than non-event exceedances, the event will need either a Tier 2 or Tier 3 demonstration.

The Guidance lists two key factors for a Tier 2 demonstration: (1) "Fire emissions and distance of fire(s) to affected monitoring site location(s)"; and (2) "Comparison of the event related O_3 concentration with non-event related high O_3 concentrations". Key factor #1 includes an emissions/distance (Q/D) threshold of 100 tons per day/kilometer to compare against the emissions from the event. If the event Q/D ratio is greater than or equal to 100 tpd/km than a Tier 2 demonstration may be appropriate. For events with Q/D less than 100 tpd/km, the Guidance recommends preparing a Tier 3 demonstration. Key factor #2 recommends limiting Tier 2 demonstrations to events where the event concentration is in the 99th percentile of a 5-year record of ozone season concentrations, or if the event concentration is one of the four highest within the event year.

A detailed discussion of the key factors for a Tier 2 demonstration in relation to the event on June 20, 2015 is included below. In summary, for the event exceedances that occurred on June 20, 2015, the Tier 2 demonstration key factor #1 is not met, as the Q/D in this event is less than 100 tpd/km. However, key factor #2 is met for this event, as 5 of the 6 exceedances were at or above the 99th percentile and the sixth exceeding site had an ozone concentration that was the third highest in 2015. Given that only one of the two key factors was met for the event on June 20, 2015, this documentation includes evidence sufficient to satisfy a Tier 3 demonstration. The appropriate level of evidence needed for the Tier 3 demonstration has been discussed with EPA Regional IX staff prior to submittal of this documentation.

Tier 2 Key Factor #1

Key factor #1 for a Tier 2 demonstration requires the estimation of daily emissions of the wildfire to produce a daily ratio (Q/D) of total tons per day of NO_x and VOC divided by the distance of the wildfire to the affected ozone monitors. If the Q/D for the event is 100 tpd/km or greater, a Tier 2 demonstration is sufficient. If the Q/D is less than 100 tpd/km, a Tier 3 demonstration is recommended.

For the event on June 20, 2015 the U.S. Forest Service BlueSky Playground tool 2.0 beta (http://www.airfire.org/data/playground/) was used to estimate the emissions of NO_x and VOC emitted by the Lake Fire. The central coordinates for the Lake Fire were entered into the tool. Default fuels data for those coordinates was selected, as well as a moisture level of "dry", given the area's prolonged drought conditions. According to the tool, from June 17, 2015 to June 19, 2015 the Lake Fire emitted a total of 1,071.09 tons of NO_x and 23,784.43 tons of VOC, for a combined 3-day total of 24,855.52 tons of NO_x and VOC. The exceeding Mesa monitor is located near the center of the nonattainment area and sits approximately 460 km east-southeast from the Lake Fire. This produces a 3-day emissions/distance ratio (Q/D) of 54 tons of VOC and NO_x per km. Figure 3–7 includes a map showing the distance of the Lake Fire to the Mesa monitor.

Since the Lake Fire experienced rapid growth over the first three days, the majority of emissions occurred on June 18, 2015 and June 19, 2015. Using fire perimeter data for those days, a ratio of 21.6 tons/km is produced on June 18, 2015, with 32.1 tons/km produced on June 19, 2015. It is primarily the ozone and ozone precursor emissions from these two days that were transported to the nonattainment area and caused the exceedances on June 20, 2015. While the daily ratios are under the recommended 100 tpd/km threshold mentioned in the Guidance, the weight of evidence presented throughout this documentation clearly indicates ozone impacts throughout Arizona and the Maricopa nonattainment area from the Lake Fire emissions.

Additionally, while the Wildfire Guidance uses Q/D as a screening tool for the level of documentation needed in an event demonstration, it is important to point out that academic research[1] on the behavior of ozone production from a wildfire generally concludes that ozone production may increase with distance from the wildfire. This observed behavior is not represented accurately in the Q/D ratio and may run counter to the assumptions of a Q/D ratio in many cases. As such, more weight should be given to direct evidence that the wildfire emissions affected the monitors (e.g., observed ozone levels, smoke distribution maps, timing and spatial distribution of NO_2 and $PM_{2.5}$, etc.) than relying on the Q/D ratio to represent relative levels of ozone production as distance from the wildfire increases.

[1] Jaffe and Widger, 2012. Ozone production from wildfires: A critical review. Atmospheric Environment 51, 1-10.

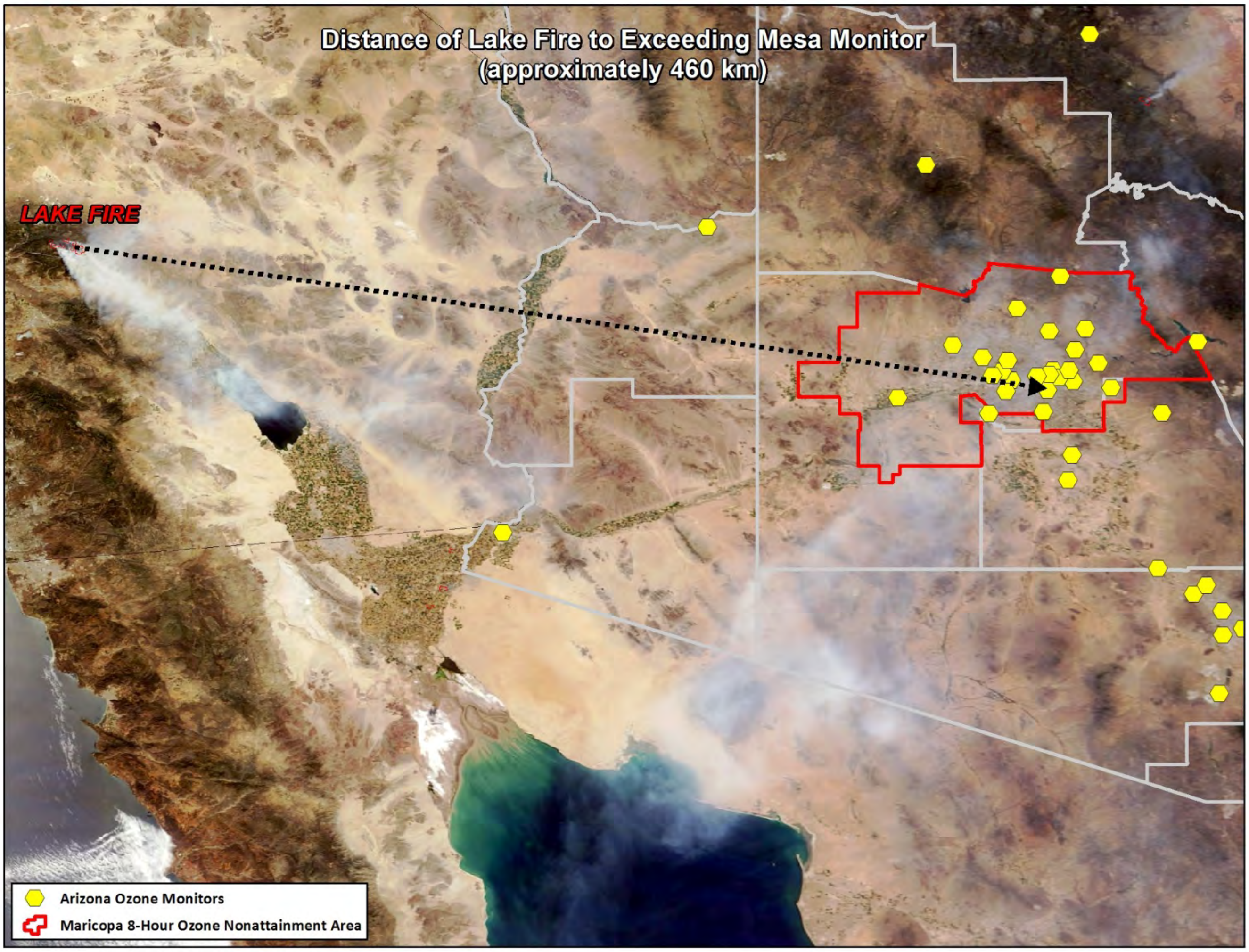

Figure 3-7. Map showing distance of Lake Fire to affected ozone monitors in the Maricopa nonattainment area (460 km).

Tier 2 Key Factor #2

The second key factor in a Tier 2 demonstration involves a comparison of the event concentration to the historical distribution of ozone concentrations at the affected monitor. This key factor is considered met when the event concentration is in the 99^{th} or higher percentile of the 5-year distribution of ozone monitoring data, or is one of the four highest ozone concentrations within the exceedance year.

Plots showing this comparison at each of the six exceeding monitors have already been presented earlier in this section (see Figures 3–1 through 3–6). Those plots show that five of the six exceeding monitors had event concentrations that were at or above the 99^{th} percentile of the 5-year historical ozone season concentrations. For the one exceeding monitor that had an event concentration below the 99^{th} percentile (Pinnacle Peak), the event was the third highest ozone concentration recorded in 2015. Therefore, the event concentrations on June 20, 2015 meet the requirements of key factor #2.

Additional Evidence of a Clear Causal Relationship

In addition to evaluating key factors, the Wildfire Guidance requires a clear causal relationship demonstration to provide evidence showing: (1) that the wildfire emissions were transported to the affected monitor; and (2) that the wildfire emissions affected the monitored ozone concentrations. The following subsections provide multiple pieces of evidence demonstrating that the emissions from the fire were both transported to the monitors and affected the ozone concentrations at the monitors in the Maricopa nonattainment area.

The Wildfire Guidance suggests that in the case of a Tier 3 demonstration, the inclusion of additional evidence that the wildfire caused the ozone exceedance may be required. The Guidance provides three additional sources of evidence that may be used in a Tier 3 demonstration: (1) Comparison of ozone concentrations on meteorologically similar days ("matching days" analysis); (2) Statistical regression modeling; and (3) Photochemical modeling. For this documentation, statistical regression modeling in the form of multiple variable regression analysis was used to provide the additional evidence sought in a Tier 3 demonstration. Additionally, as this documentation is being submitted prior to the adoption of the EPA proposed changes to the Exceptional Events Rule, the statistical regression modeling presented in this documentation also satisfies the current rule requirement in 40 CFR Section 50.14(c)(3)(iv) by providing a demonstration that "there would have been no exceedance or violation but for the event." A discussion on the statistical regression modeling is included in the following subsections and in detail in Appendix D.

Evidence that the Wildfire Emissions were Transported to the Affected Monitors

HYSPLIT Back Trajectories

The National Oceanic and Atmospheric Administration (NOAA) HYSPLIT model was run to produce back trajectories of air parcel movement at lower and upper altitudes (100 and 1500 meters) for each of the six exceeding ozone monitoring sites. The Wildfire Guidance recommends selecting heights no lower than 100 meters to avoid interference with the terrain and no higher than 1500 meters to confine the air parcel to within the mixing layer. The back trajectories are intended to represent the transport of air from areas near the Lake Fire and its associated smoke to the Maricopa nonattainment area on June 20, 2015. Figures 3–8 through 3–13 display the lower and upper back trajectories at each exceeding monitoring site on June 20, 2015, overlaid on a satellite photo of smoke from the Lake Fire on June 19, 2015. The back trajectories end at the hour with the highest ozone concentration on June 20, 2015 for each of the exceeding monitors. Each hour of the 36-hour back trajectory is represented by a dot on the Figures. The back trajectory hour at which the satellite photo on June 19, 2015 was taken (12:00 pm) is represented as a star on the Figures. In most cases the star is located either directly in visible smoke from the Lake Fire or very near visible smoke from the Lake Fire. The figures clearly show that the air from areas near or affected by, smoke, ozone and ozone precursor emissions from the Lake Fire, reached the exceeding Maricopa nonattainment area monitors. The output pdf files from the NOAA HYSPLIT model back trajectory runs are included in Appendix C.

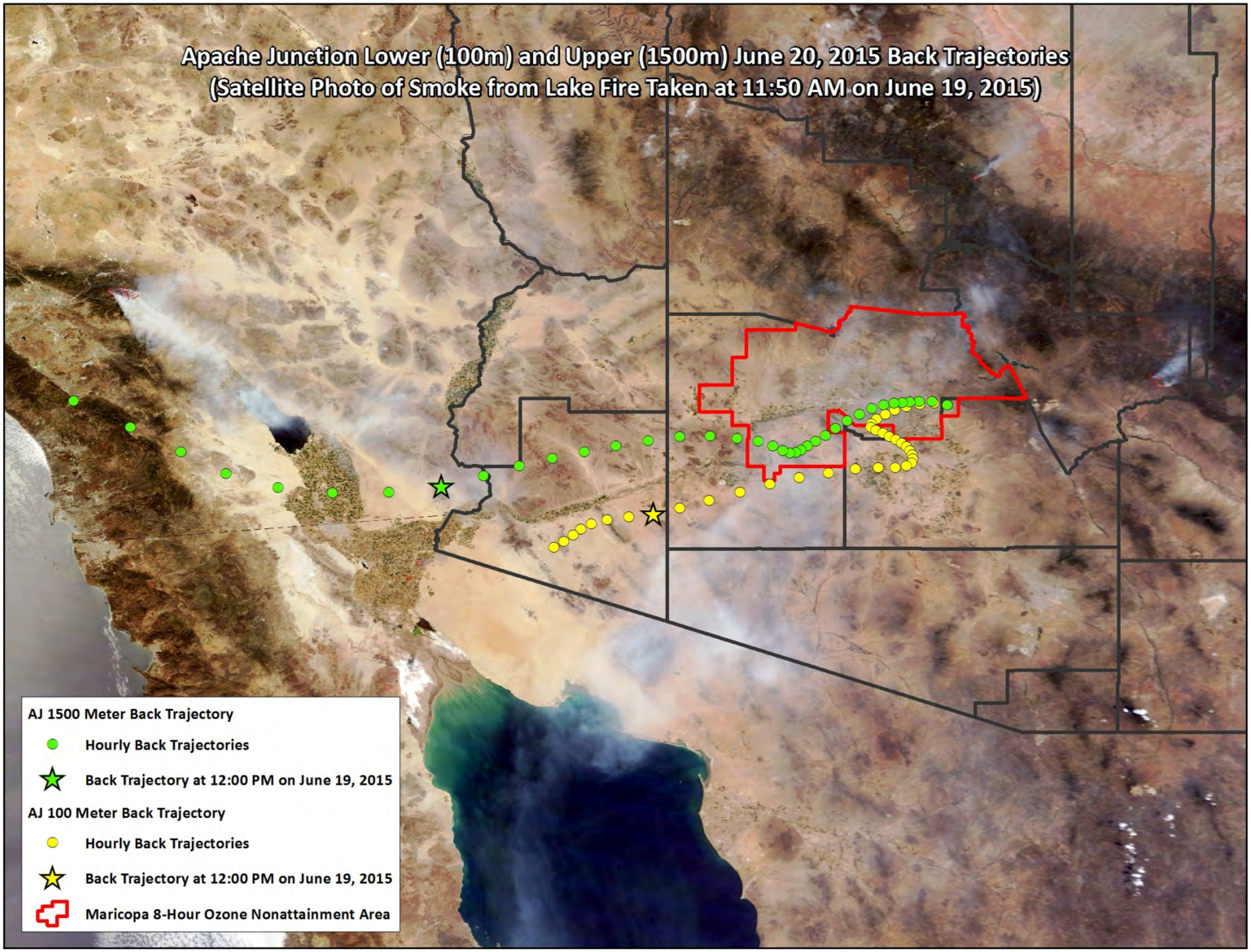

Figure 3-8. Lower (yellow) and upper (green) back trajectories for the Apache Junction monitor.

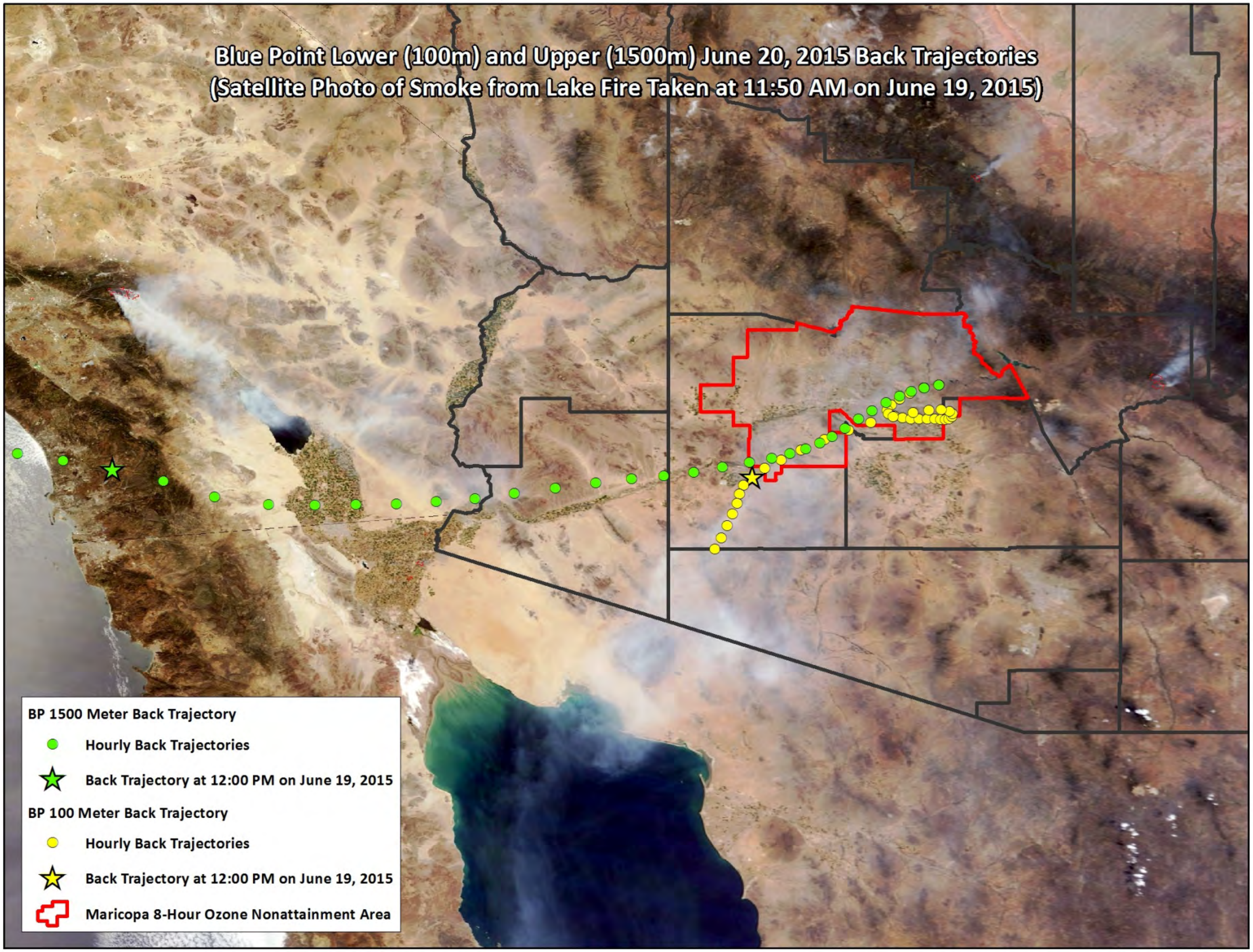

Figure 3-9. Lower (yellow) and upper (green) back trajectories for the Blue Point monitor.

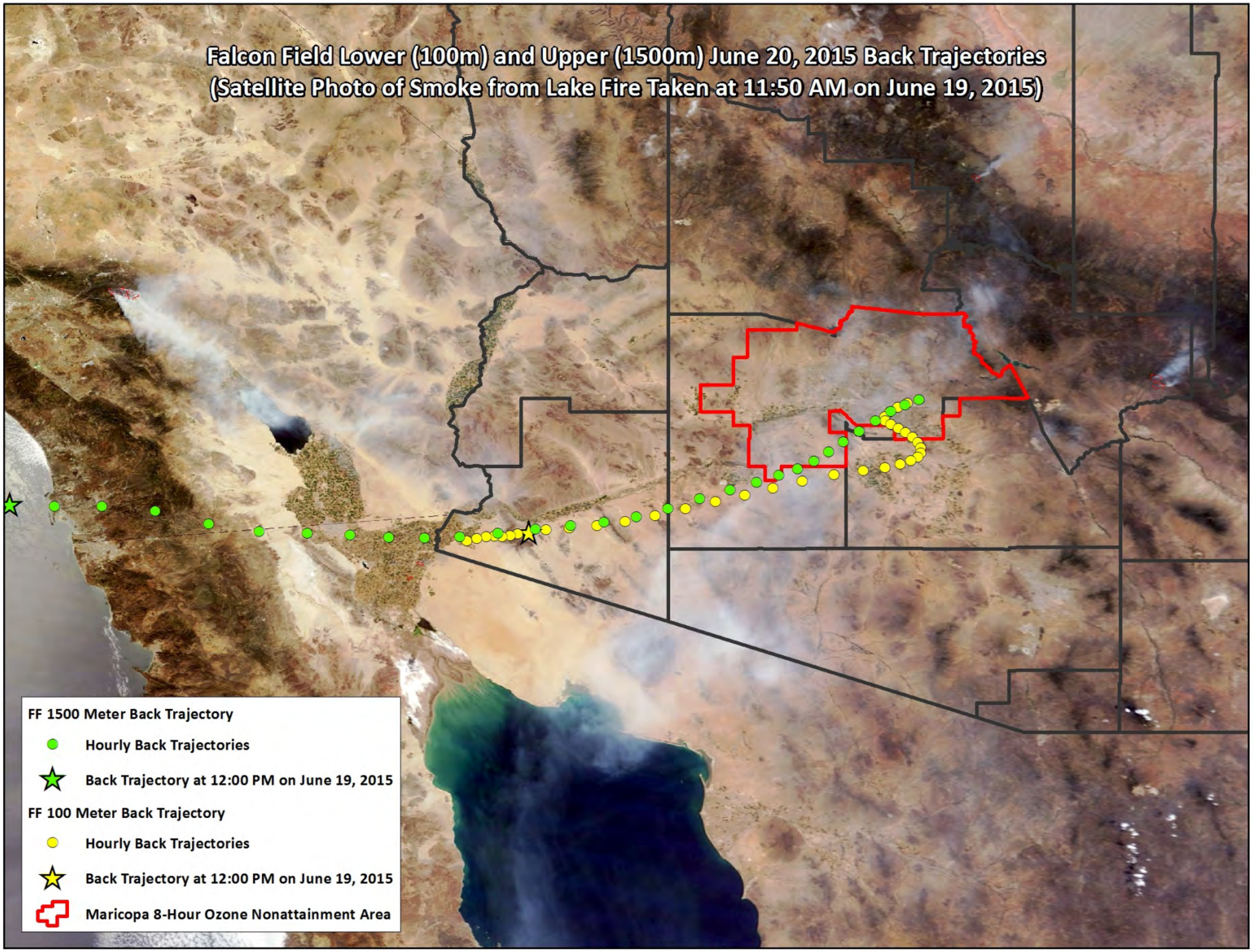

Figure 3-10. Lower (yellow) and upper (green) back trajectories for the Falcon Field monitor.

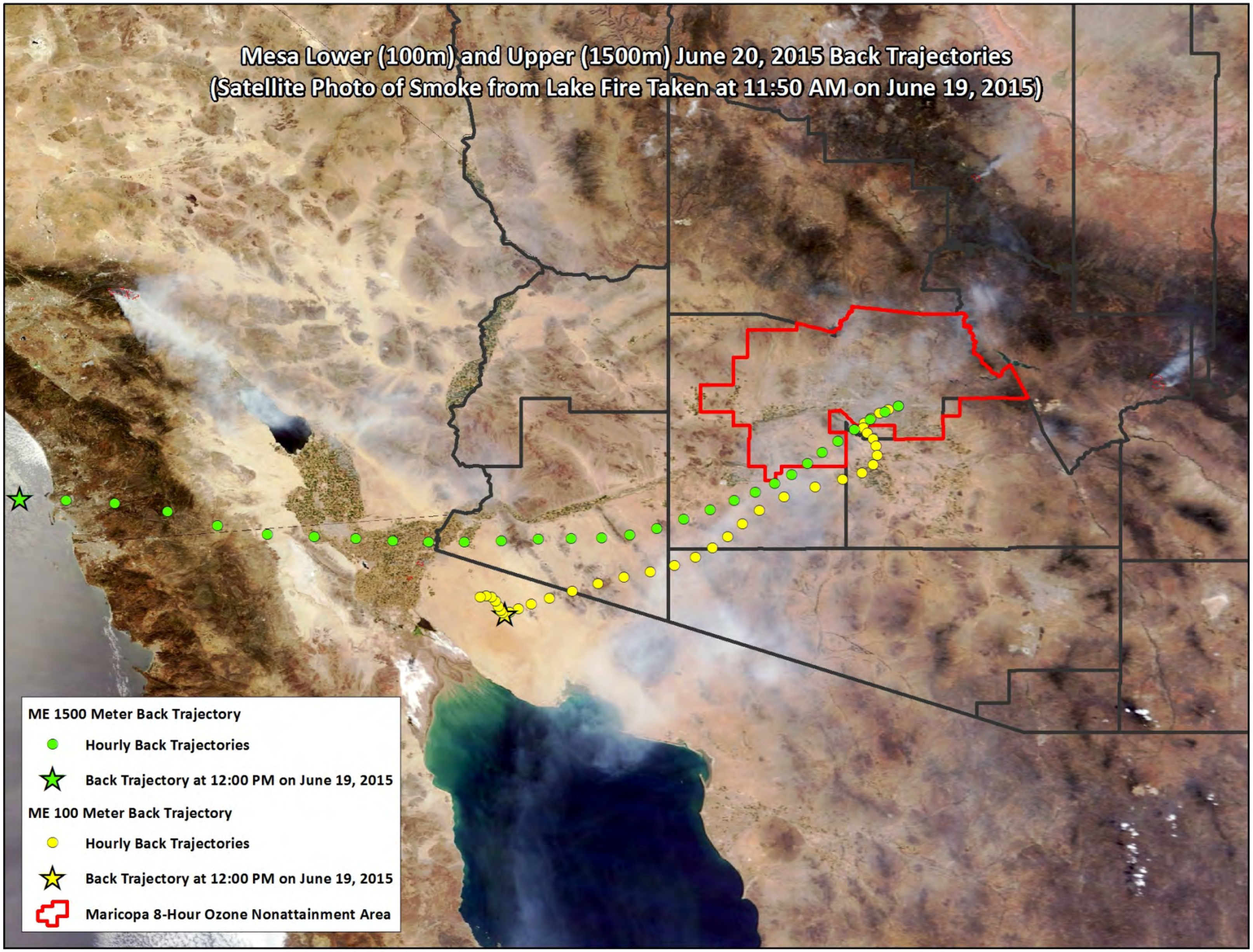

Figure 3-11. Lower (yellow) and upper (green) back trajectories for the Mesa monitor.

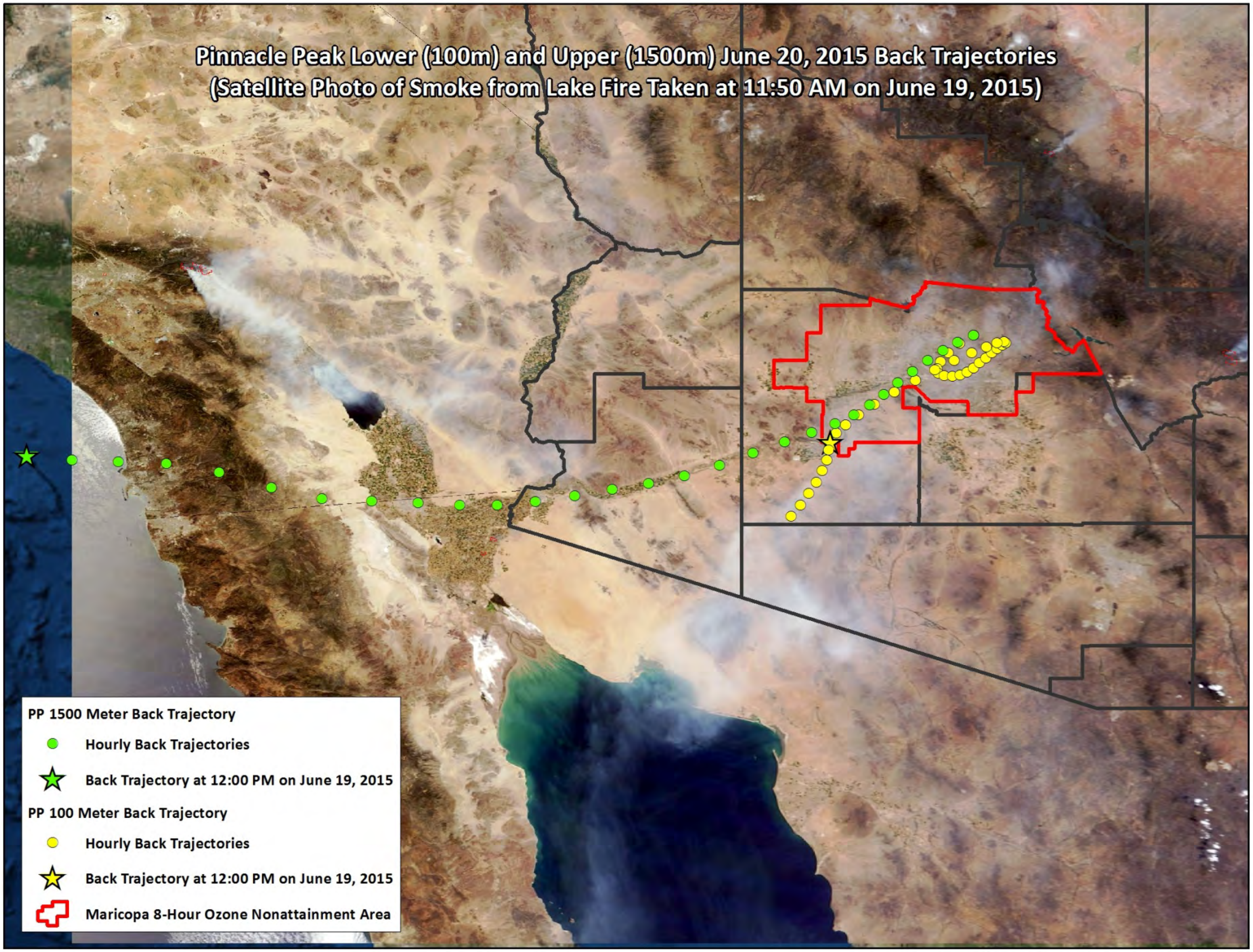

Figure 3-12. Lower (yellow) and upper (green) back trajectories for the Pinnacle Peak monitor.

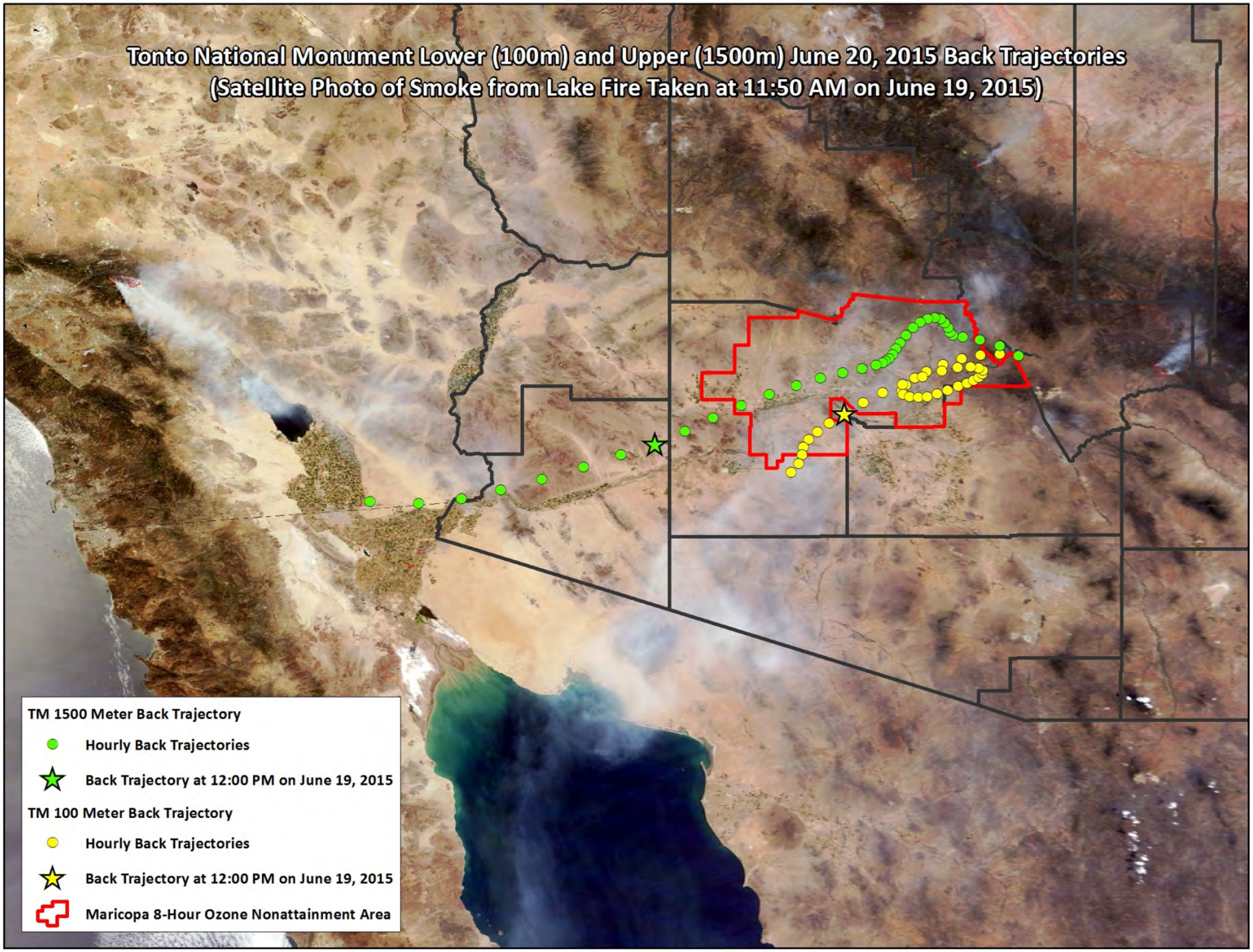

Figure 3-13. Lower (yellow) and upper (green) back trajectories for the Tonto National Monument monitor.

NOAA Smoke Maps

A second source of data showing that emissions and smoke from the Lake Fire reached the Maricopa nonattainment area is NOAA's Hazard Mapping System Fire and Smoke Product (HMS) which provides maps of smoke dispersion (see http://www.ospo.noaa.gov/Products/land/hms.html). Figures 3–14 through 3–17 show the dispersion of smoke across southeastern California, Arizona and northern Mexico on June 17-20, 2015. These maps clearly indicate that smoke from the Lake Fire and other smaller fires reached the Maricopa nonattainment area.

Regional and Local Meteorology

Examinations of the regional and local meteorological conditions on June 17 -20, 2015 also favor the transport of smoke, ozone and ozone precursor emissions from the Lake Fire to the Maricopa nonattainment area. Figure 3–18 displays the regional upper level winds on June 17-20, 2015, showing a general west to east flow over southeastern California and across Arizona. Local nonattainment area surface winds on June 17-20, 2015 are represented as wind roses in Figure 3–19 and reveal a dominant pattern of surface winds generally coming from the west and moving towards the east. Nonattainment area surface winds were calmest on June 20, 2015 at the exceeding monitors, allowing for the transported ozone and ozone precursor emissions from the wildfire to pool longer at the exceeding monitors. Upper and lower level wind speeds increased again on June 21, 2015, transporting ozone out of the Maricopa nonattainment area and lowering maximum daily ozone concentrations by up to 25 parts per billion. National Weather Service hourly meteorological data on June 17-21, 2015 at the Sky Harbor International Airport are included in Appendix B.

The combination of these data sources provide strong evidence that smoke, ozone, and ozone precursor emissions from the Lake Fire were transported to the exceeding monitors.

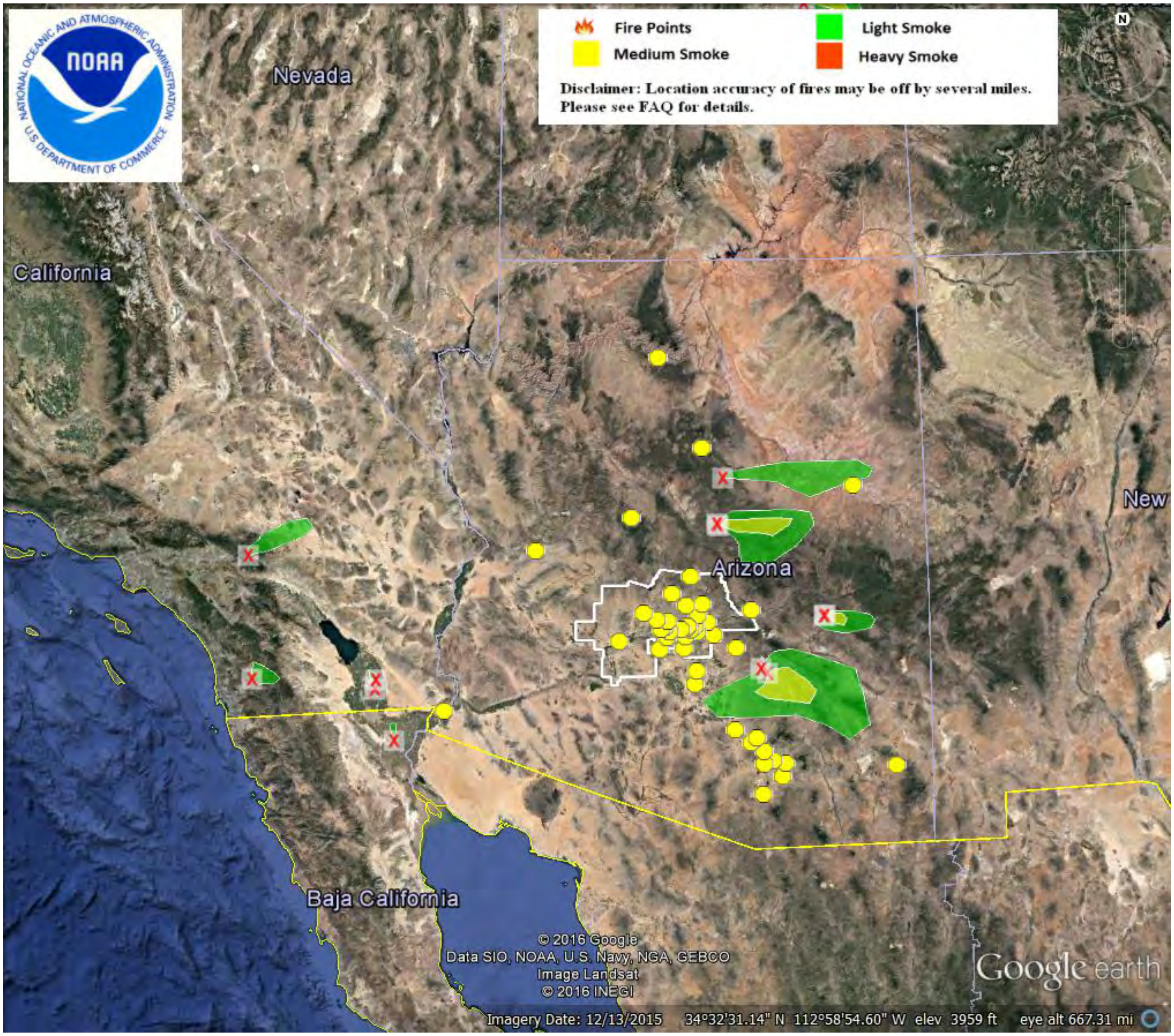

Figure 3-14. NOAA smoke map for June 17, 2015.

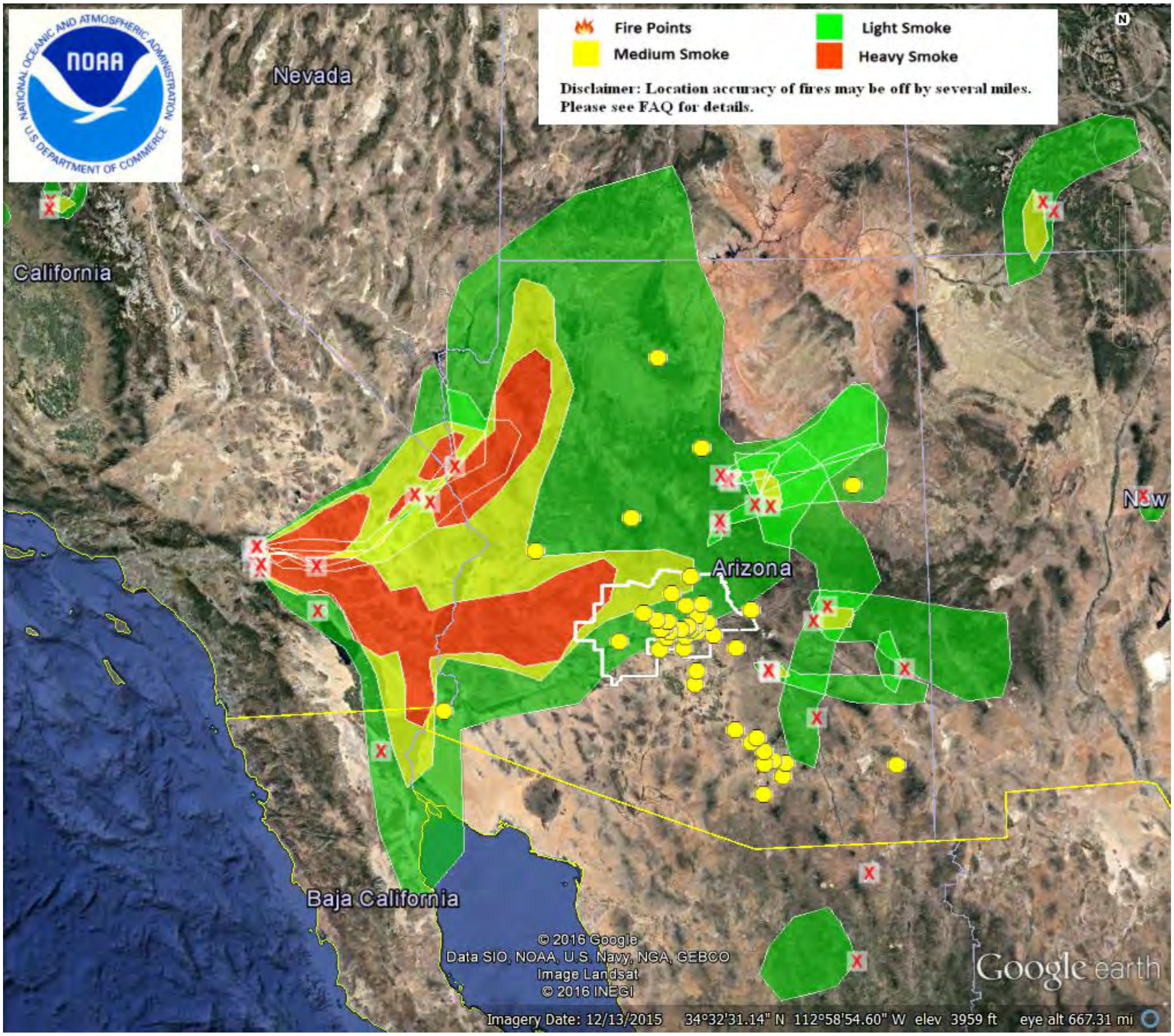

Figure 3-15. NOAA smoke map for June 18, 2015.

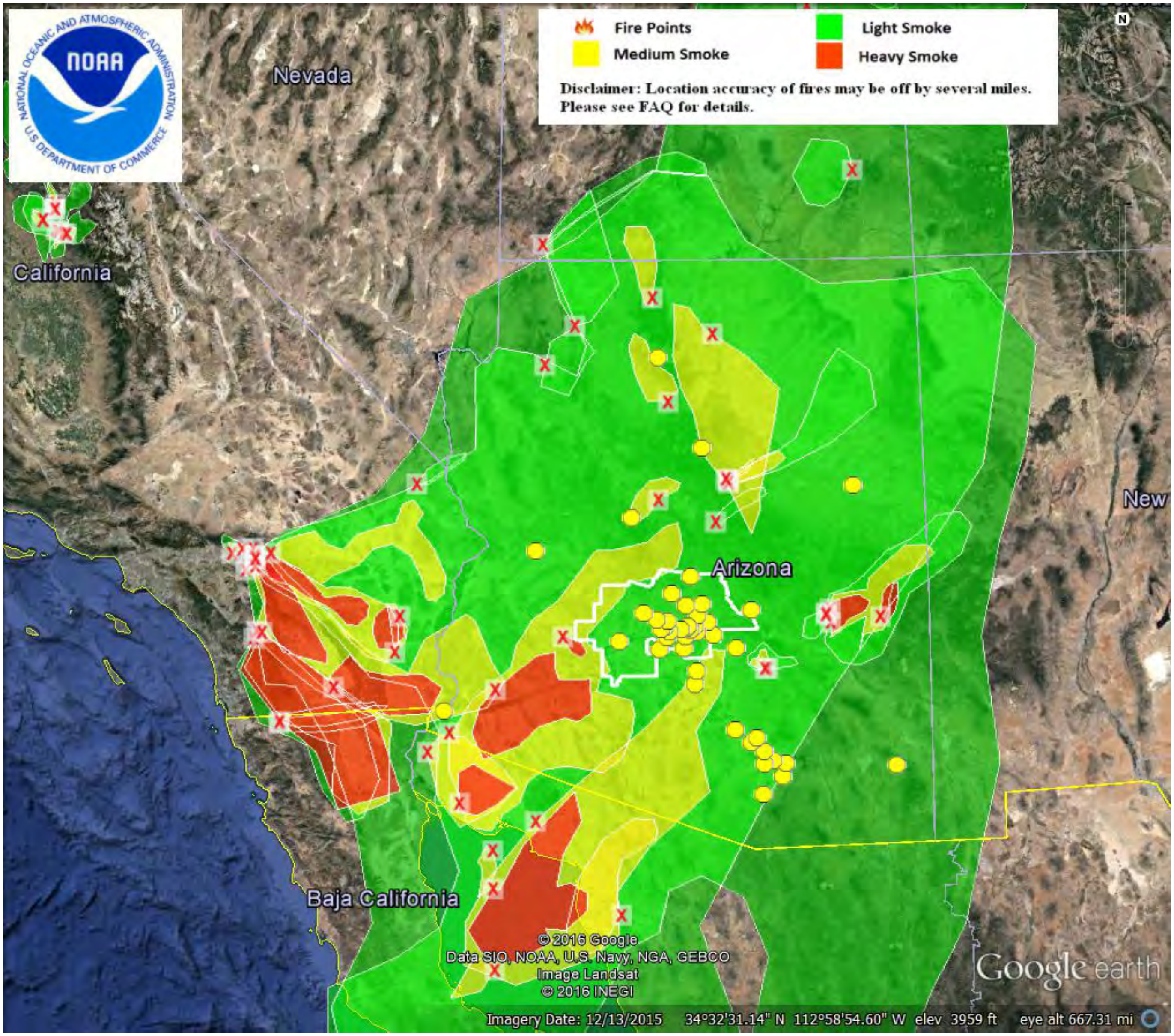

Figure 3-16. NOAA smoke map for June 19, 2015.

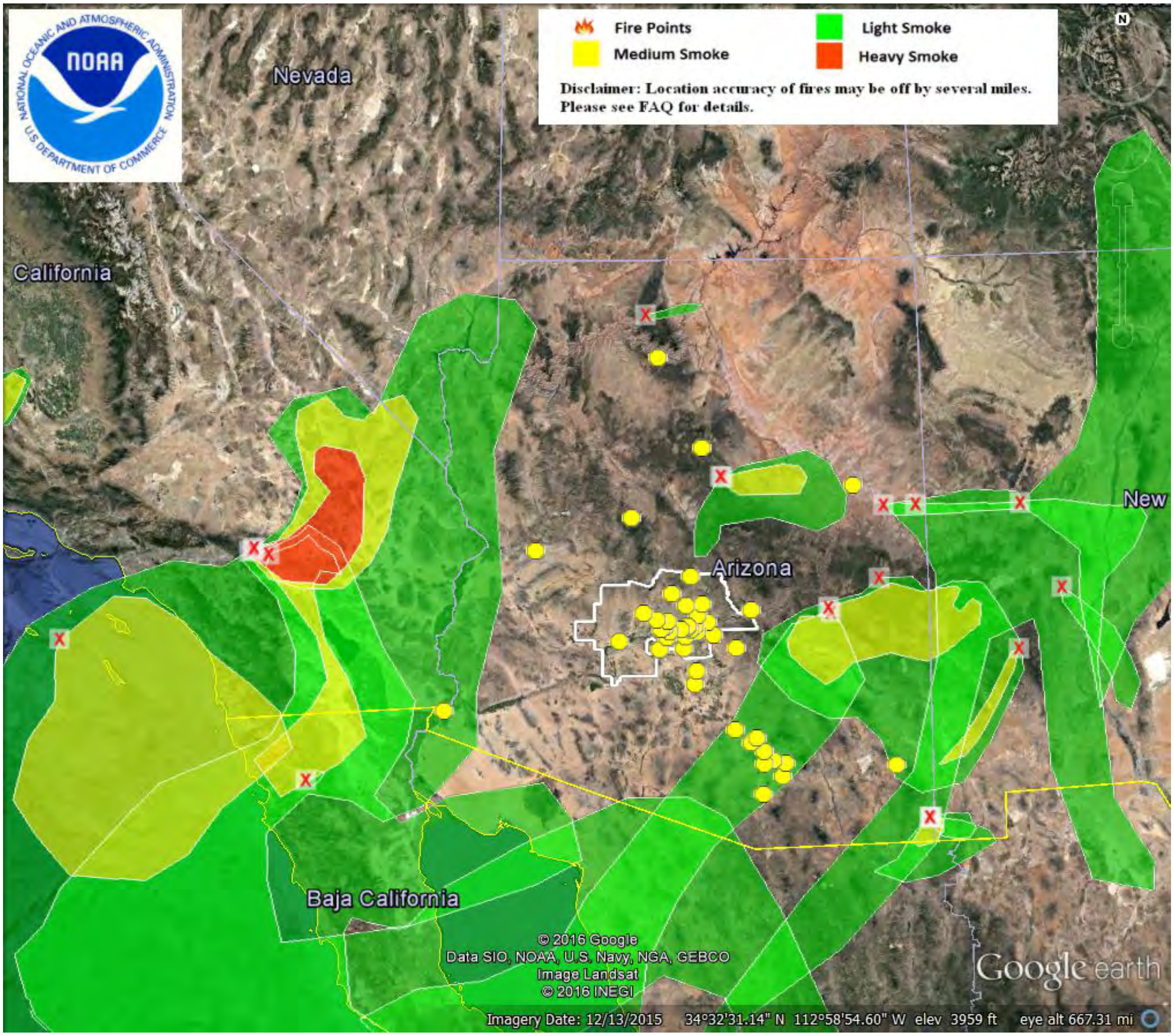

Figure 3-17. NOAA smoke map for June 20, 2015.

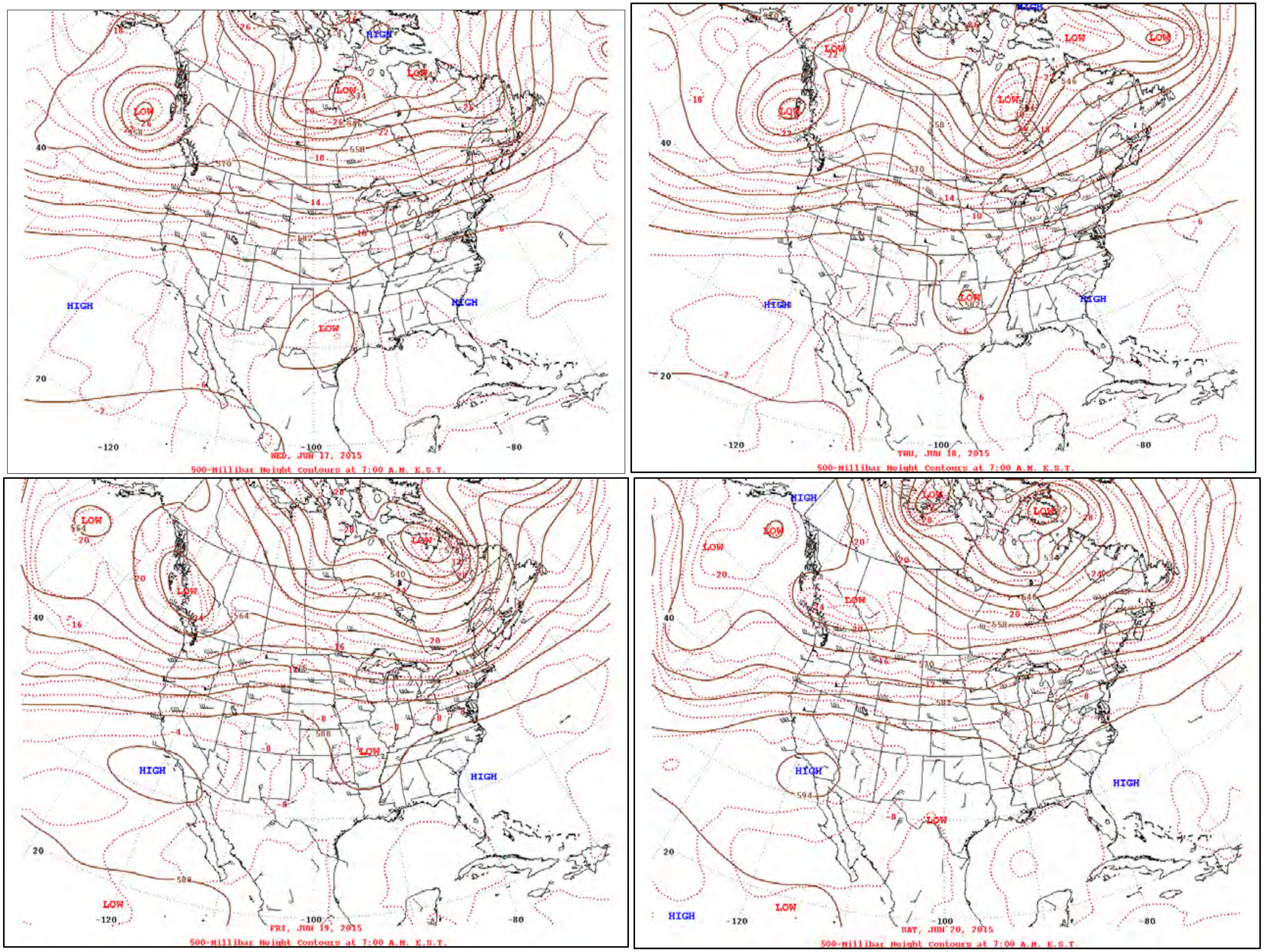

Figure 3-18. NWS upper level (500 mb) winds on June 17-20, 2015.

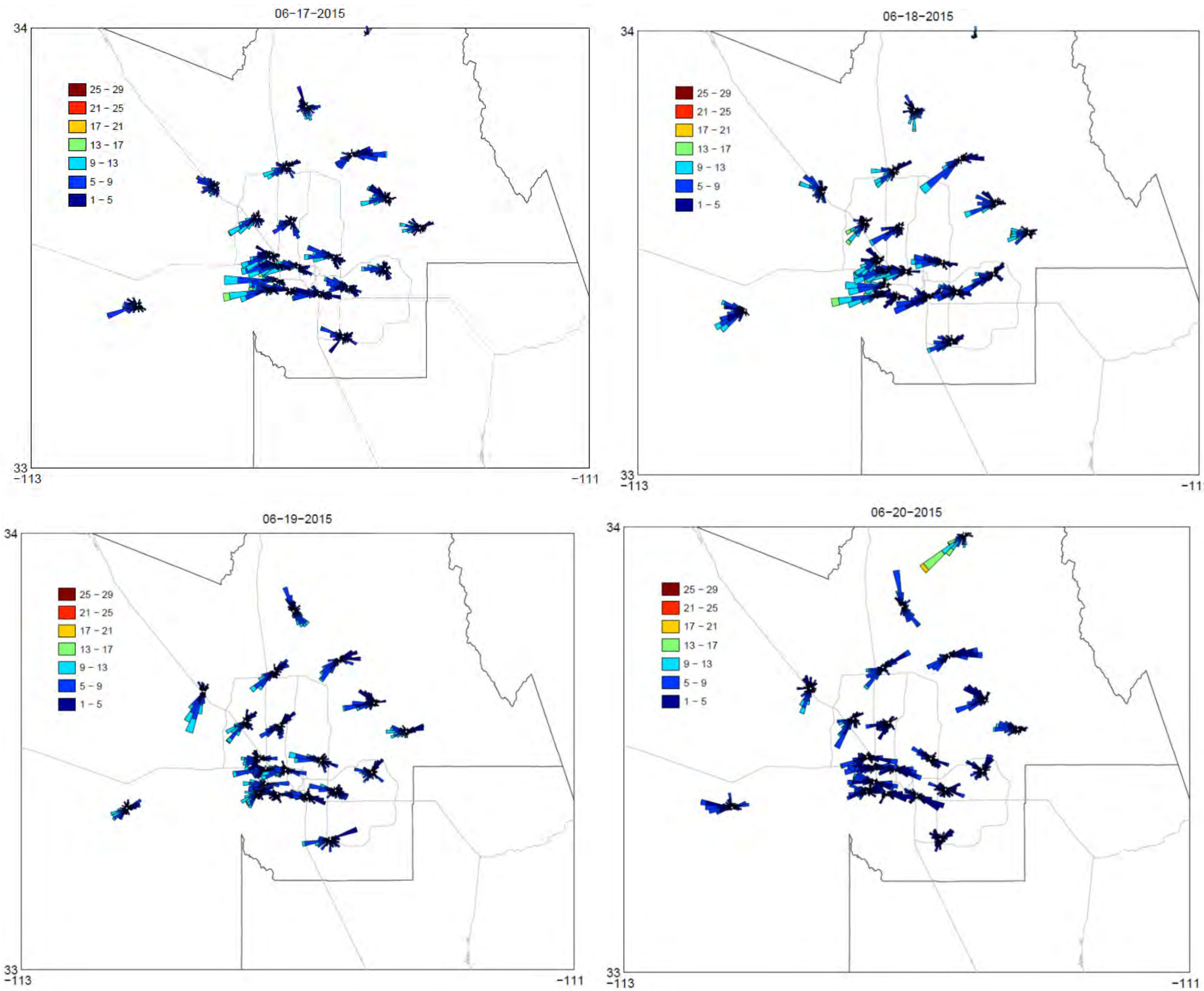

Figure 3-19. 24-Hour nonattainment area wind roses on June 17-20, 2015.

Evidence that the Wildfire Emissions Affected the Monitors

Concurrent Rise in Ozone Concentrations

As discussed above, satellite photos, back trajectories, smoke maps and prevailing meteorological conditions confirm the transport of smoke, ozone, and ozone precursor emissions from the Lake Fire to Arizona and the Maricopa nonattainment area. Concurrent with the arrival of smoke, ozone, and ozone precursor emissions, were corresponding rises in ozone concentrations across central and northern Arizona and the Maricopa nonattainment area. Rises in ozone concentrations at monitors in Yuma, Flagstaff and other rural locations in central and northern Arizona illustrate the widespread affect the Lake Fire had on influencing ozone concentrations throughout Arizona. Table 3–1 includes the rise in ozone concentrations at these monitoring sites over June 17-21, 2015, and Figures 3–20 through 3–24 display the rise in ozone concentrations at these sites in conjunction with satellite photos of the smoke moving west to east across Arizona on June 17-21, 2015.

Table 3-1. Change in Maximum Daily Eight-Hour Ozone Concentrations (ppm) at Alamo Lake, Flagstaff, Grand Canyon, Petrified Forest, Prescott and Yuma During June 17-21, 2015.

Monitor Location	June 17 (pre-fire)	June 18	June 19	June 20	June 21 (post-fire)	Largest ppm increase from June 17 (fire impact)
Alamo Lake	0.057	0.066	0.073	0.066	0.050	0.016, June 19
Flagstaff Middle School	0.063	0.065	0.070	0.067	0.055	0.007, June 19
Grand Canyon	0.061	0.070	0.073	0.069	0.058	0.012, June 19
Petrified Forest	0.057	0.060	0.059	0.070	0.060	0.013, June 20
Prescott College	0.059	0.064	0.068	0.067	0.049	0.009, June 19
Yuma	0.050	0.072	0.084	0.043	0.046	0.034, June 19

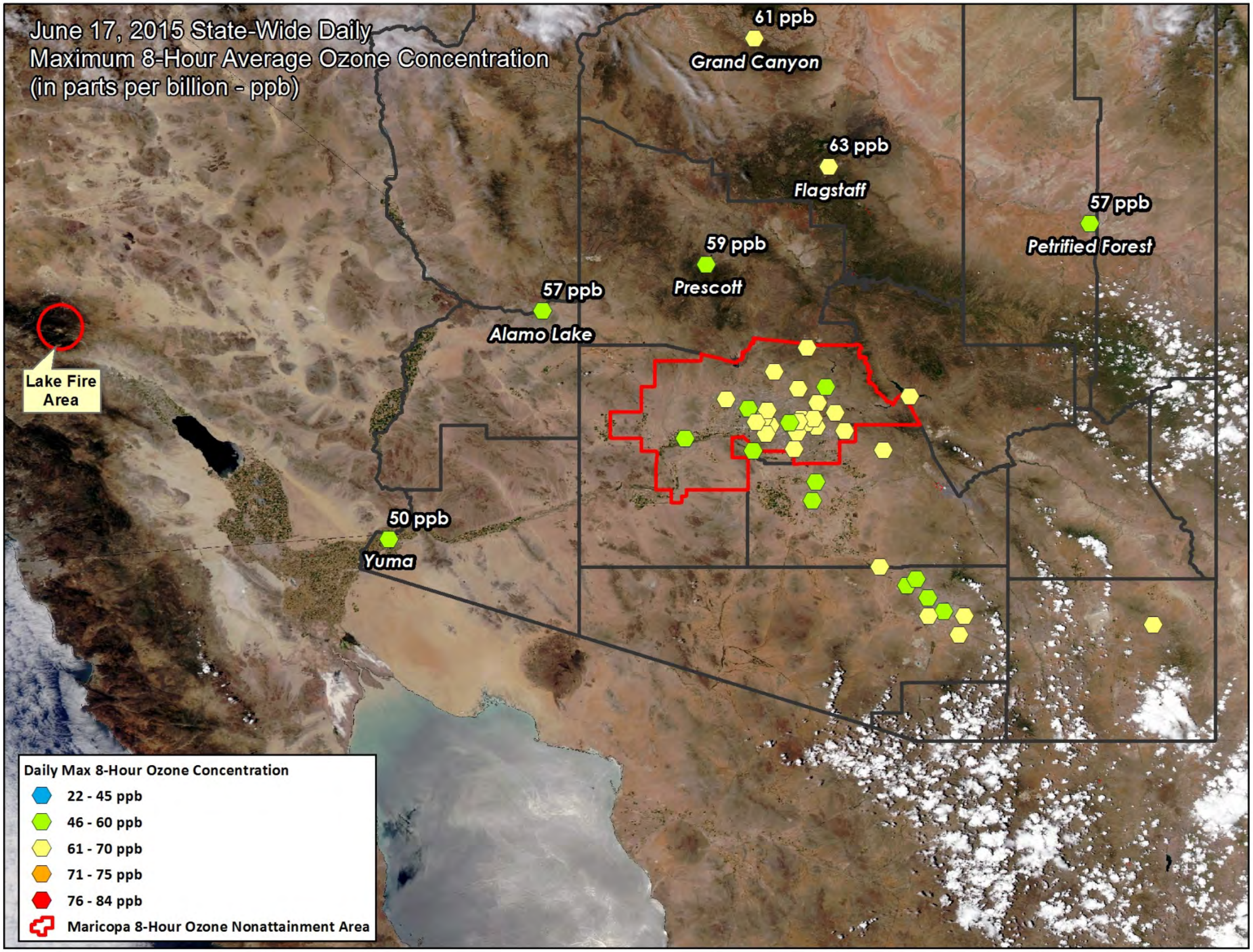

Figure 3-20. State-wide ozone concentrations on June 17, 2015.

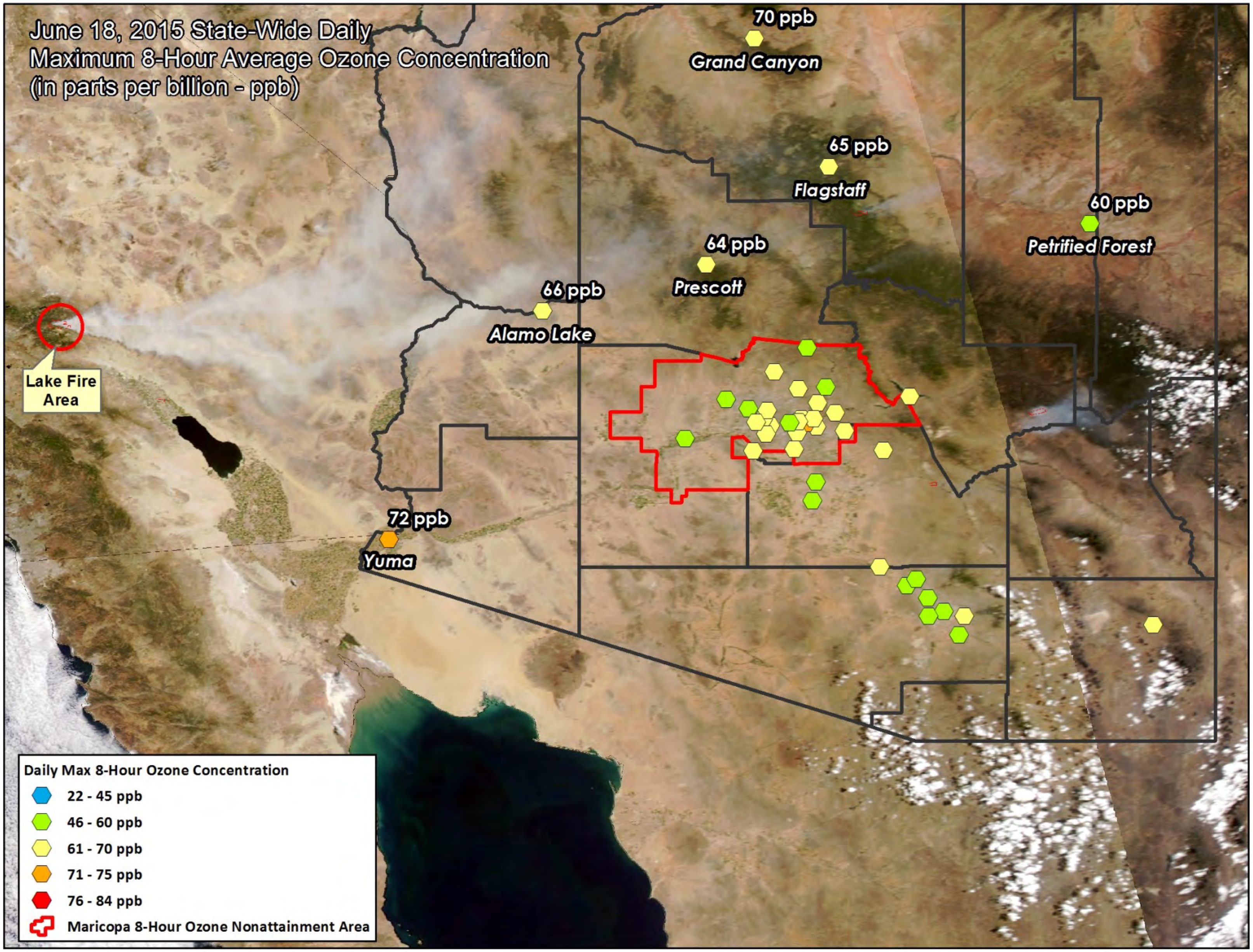

Figure 3-21. State-wide ozone concentrations on June 18, 2015.

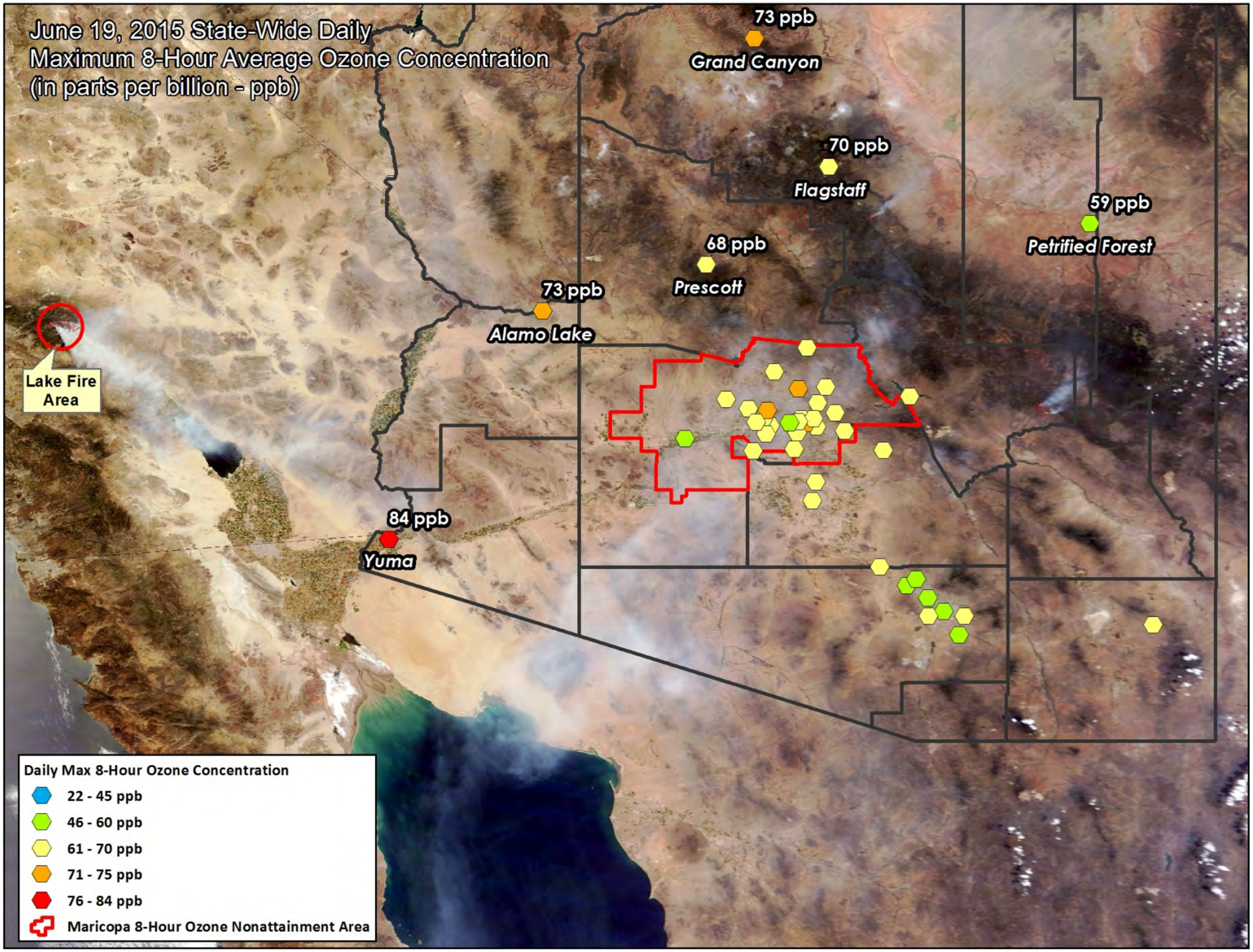

Figure 3-22. State-wide ozone concentrations on June 19, 2015.

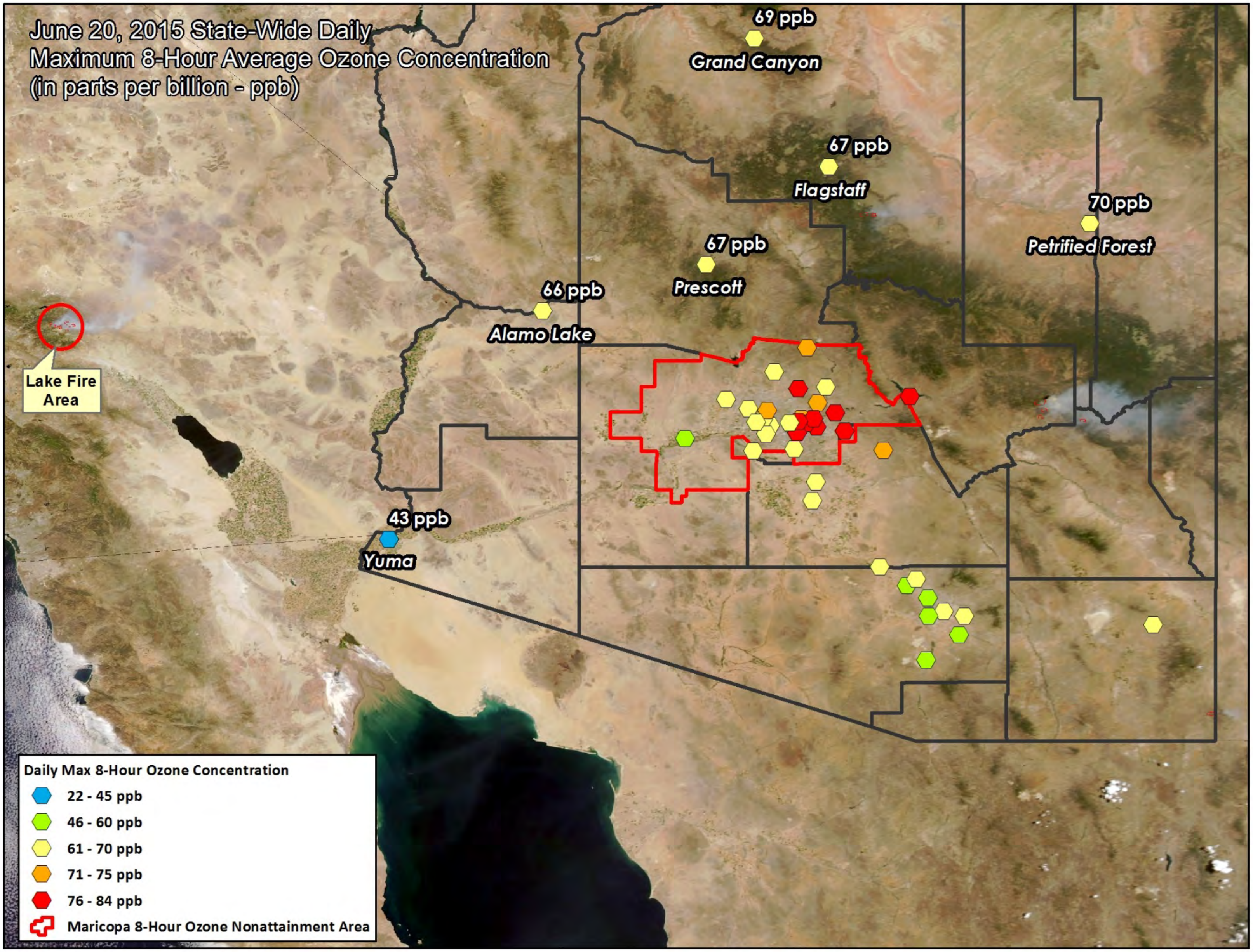

Figure 3-23. State-wide ozone concentrations on June 20, 2015.

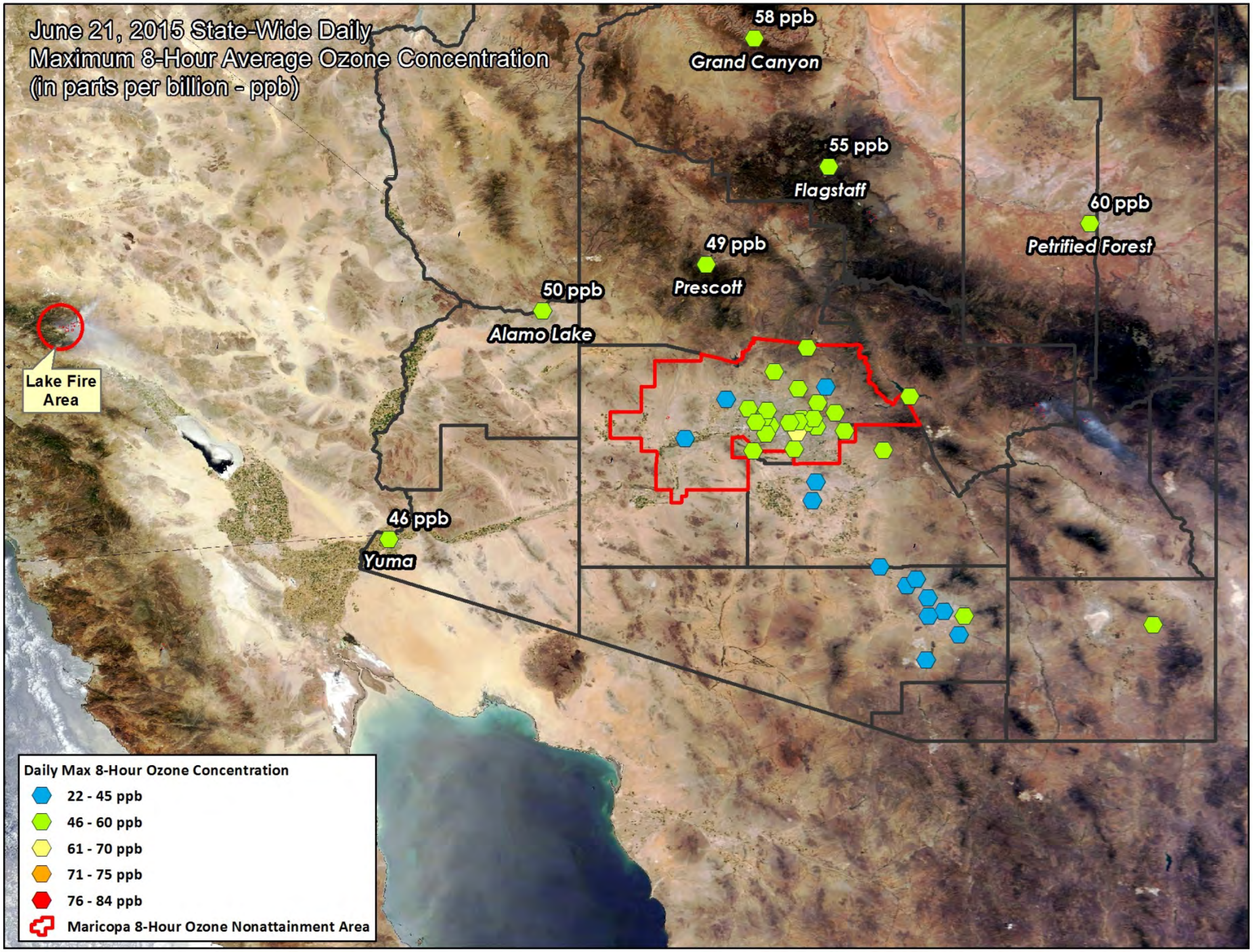

Figure 3-24. State-wide ozone concentrations on June 21, 2015.

Ozone concentrations in the Maricopa nonattainment area also show an abrupt rise on June 20, 2015, when wind speeds are less and the transported ozone and ozone precursor emissions from the Lake Fire mix with normal, seasonal nonattainment area emissions to produce ozone concentrations that resulted in exceedances of the ozone standard at six monitors. In general, the monitors that showed the highest increase in ozone due to the transported Lake Fire ozone and ozone precursor emissions were located in the eastern half of the nonattainment area. This is likely due to the prevailing surface winds that tend to flow from the west to the east in the afternoon when ozone production is at the highest. It is also likely that ozone production in these areas is more sensitive to increased NOx (NOx-limited area), than the urban core of the nonattainment area, which can at times be VOC-limited and not as sensitive to increases in NOx. Increases in NOx due to the interaction between the ozone and ozone precursor emissions from the Lake Fire are documented later in this section. Table 3–2 includes the rise in ozone concentrations at nonattainment area monitors over June 17-21, 2015, and Figures 3–25 through 3–29 display the nonattainment area ozone concentrations on June 17-21, 2015.

Table 3-2. Change in Maximum Daily Eight-Hour Ozone Concentrations (ppm) at Maricopa Nonattainment Area Monitors During June 17-21, 2015.

Monitor Location	June 17 (pre-fire)	June 18	June 19	June 20	June 21 (post-fire)	Increase from June 17 to June 20 (fire impact)
Apache Junction	0.067	0.069	0.065	0.078	0.059	0.011
Blue Point	0.065	0.066	0.067	0.077	0.052	0.012
Buckeye	0.051	0.052	0.056	0.054	0.039	0.003
Cave Creek	0.063	0.064	0.068	0.069	0.047	0.006
Central Phoenix	0.063	0.063	0.065	0.068	0.057	0.005
Dysart	0.062	0.060	0.061	0.062	0.044	0.000
Falcon Field	0.067	0.069	0.068	0.080	0.059	0.013
Fountain Hills	0.062	0.063	0.068	0.073	0.053	0.011
Glendale	0.060	0.058	0.066	0.064	0.046	0.004
Humboldt Mountain	0.062	0.059	0.069	0.073	0.050	0.011
JLG Supersite	0.066	0.069	0.066	0.068	0.054	0.002
Mesa	0.069	0.068	0.069	0.079	0.061	0.010
North Phoenix	0.068	0.070	0.071	0.073	0.055	0.005
Pinnacle Peak	0.068	0.070	0.074	0.078	0.056	0.010
Rio Verde	0.055	0.058	0.061	0.065	0.043	0.010
South Phoenix	0.065	0.063	0.065	0.067	0.058	0.002
South Scottsdale	0.059	0.060	0.059	0.070	0.053	0.011
Tonto Nat. Monument	0.063	0.069	0.067	0.079	0.054	0.016
West Chandler	0.062	0.067	0.063	0.069	0.057	0.007
West Phoenix	0.066	0.066	0.064	0.067	0.052	0.001

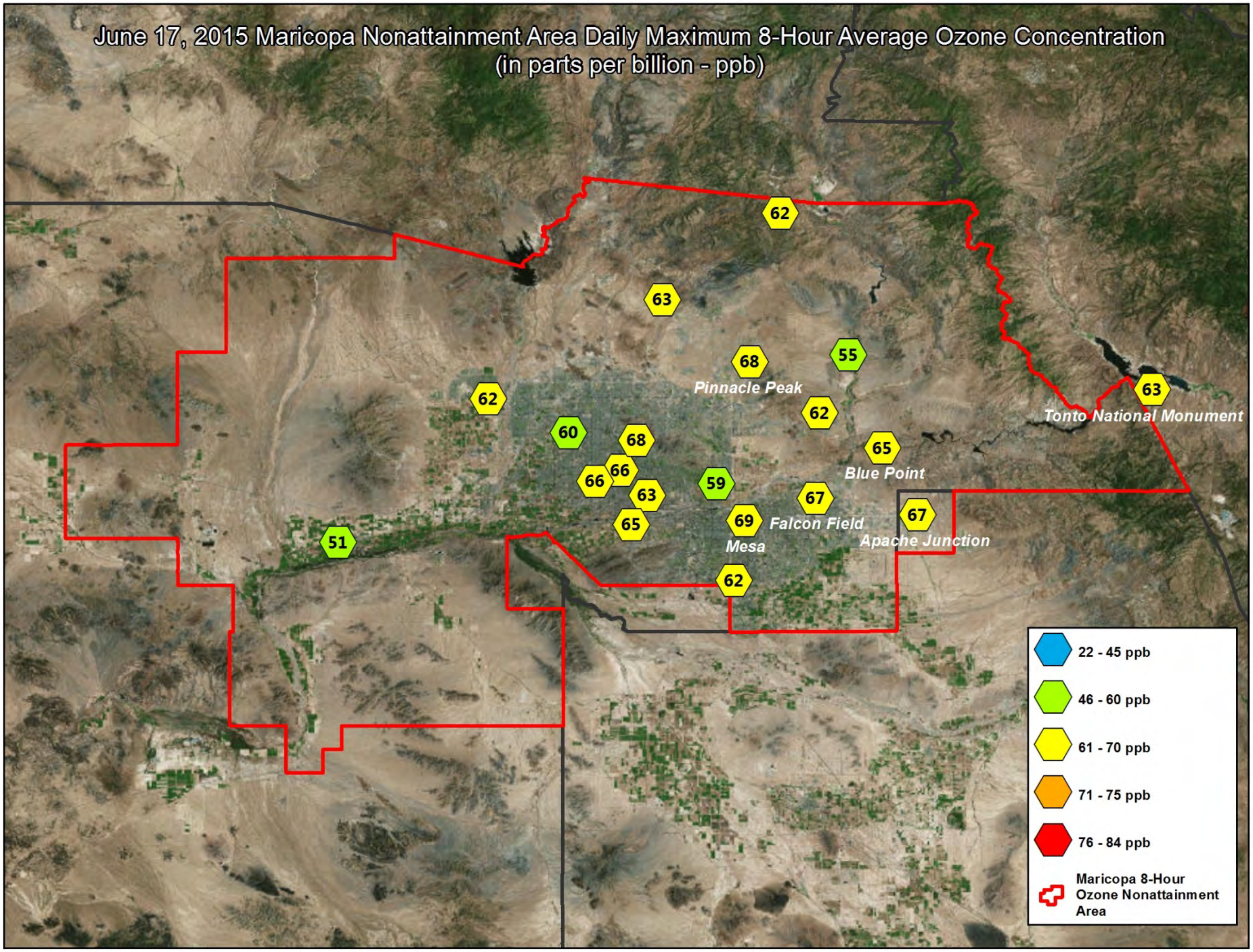

Figure 3-25. Maricopa nonattainment area ozone concentrations on June 17, 2015.

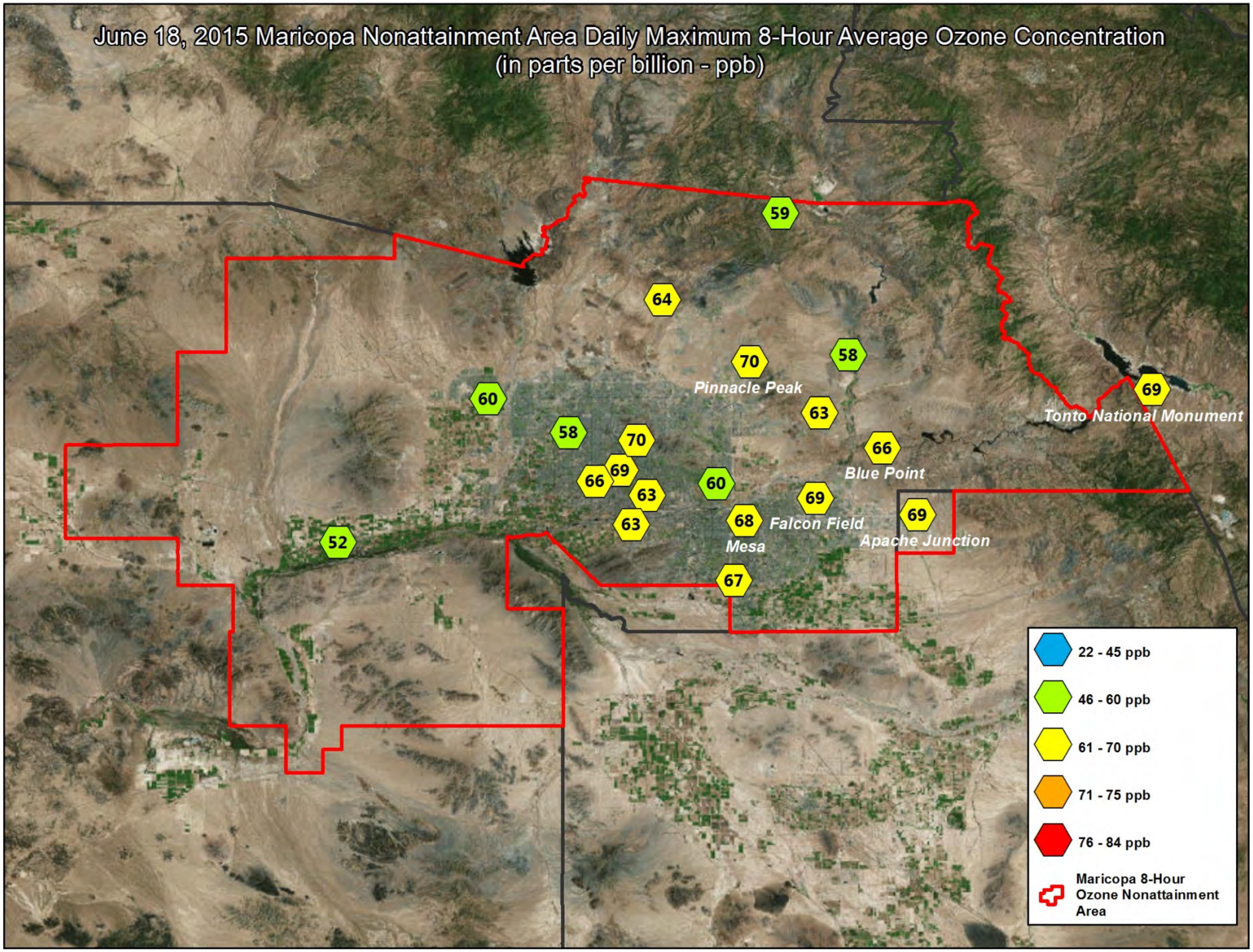

Figure 3-26. Maricopa nonattainment area ozone concentrations on June 18, 2015.

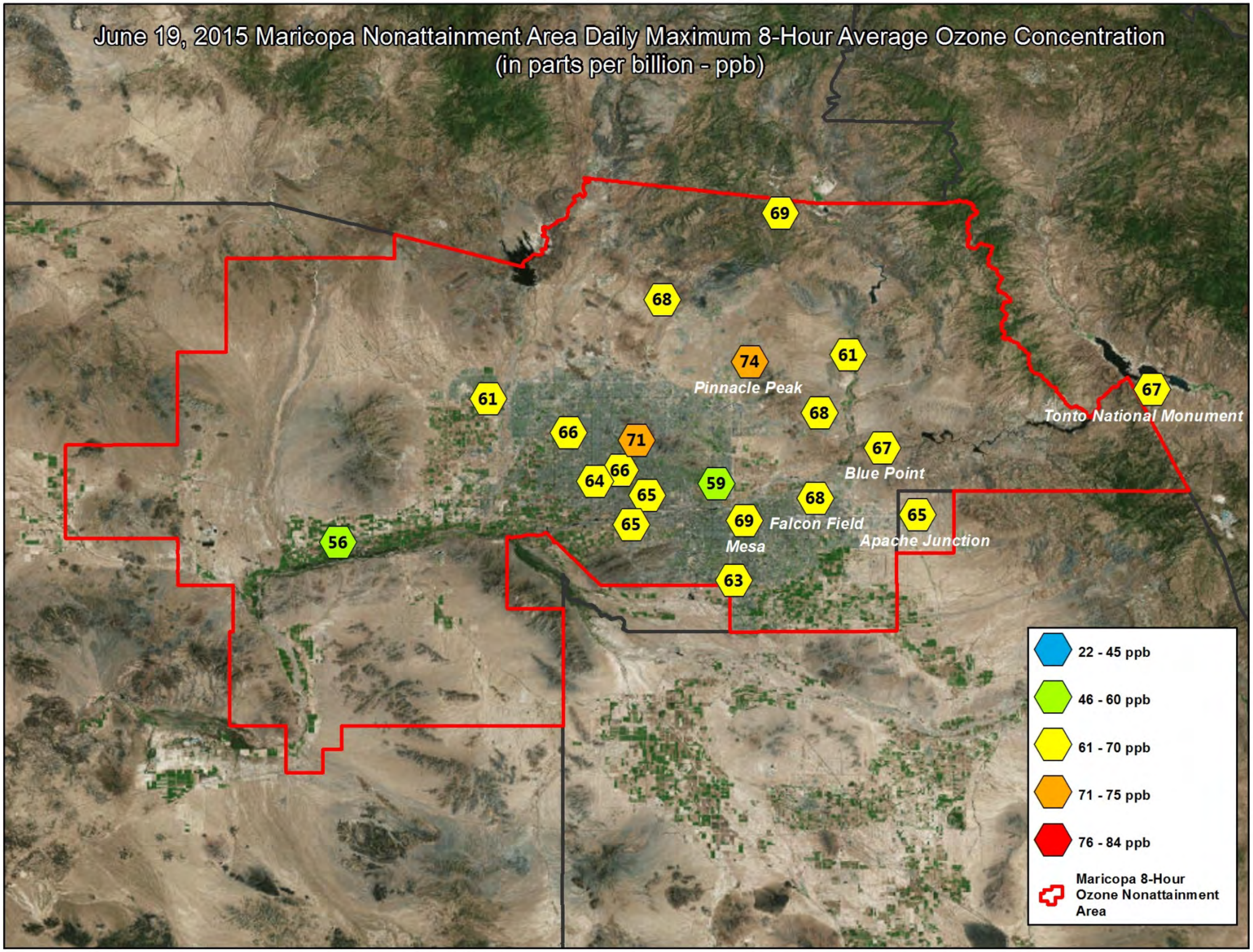

Figure 3-27. Maricopa nonattainment area ozone concentrations on June 19, 2015.

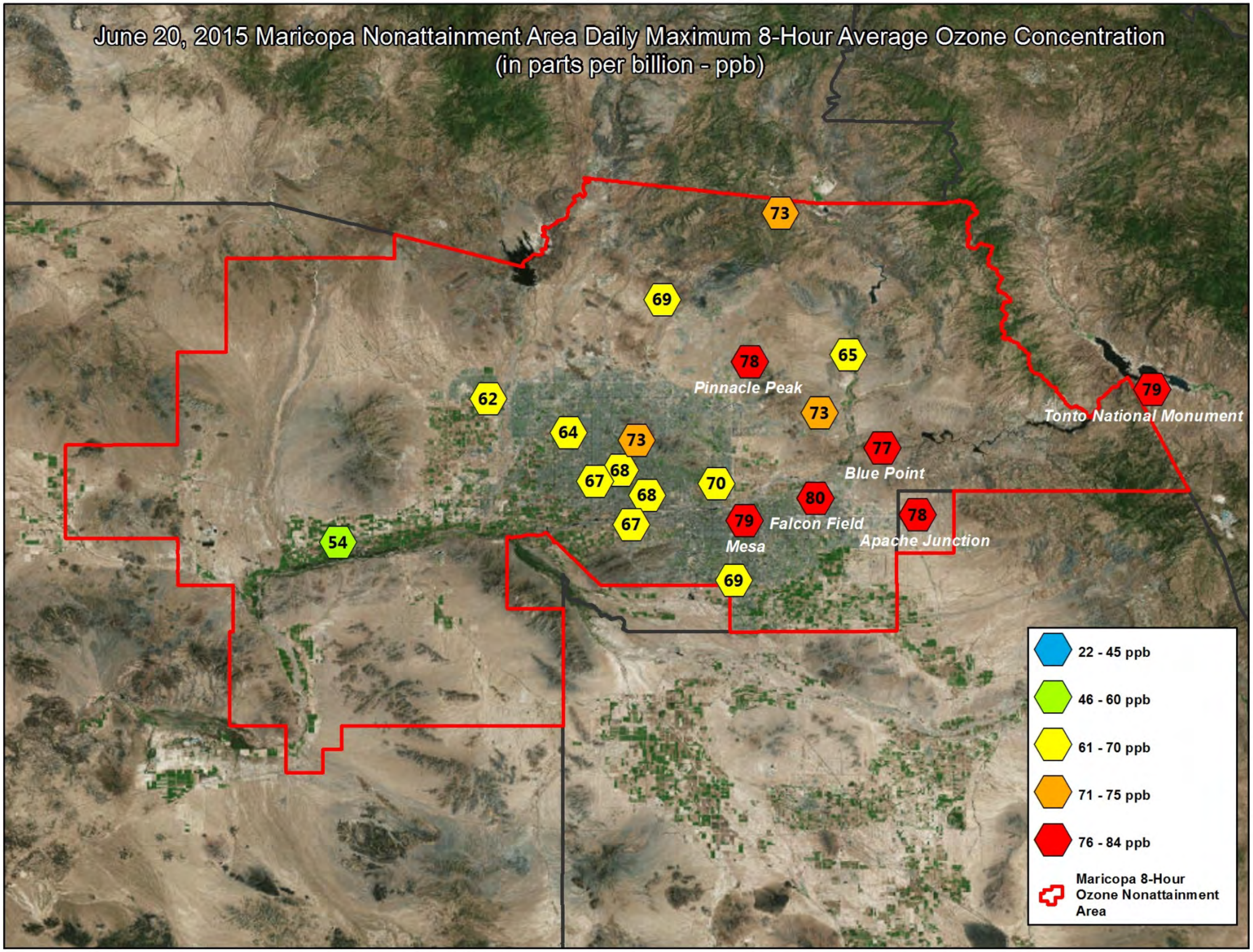

Figure 3-28. Maricopa nonattainment area ozone concentrations on June 20, 2015.

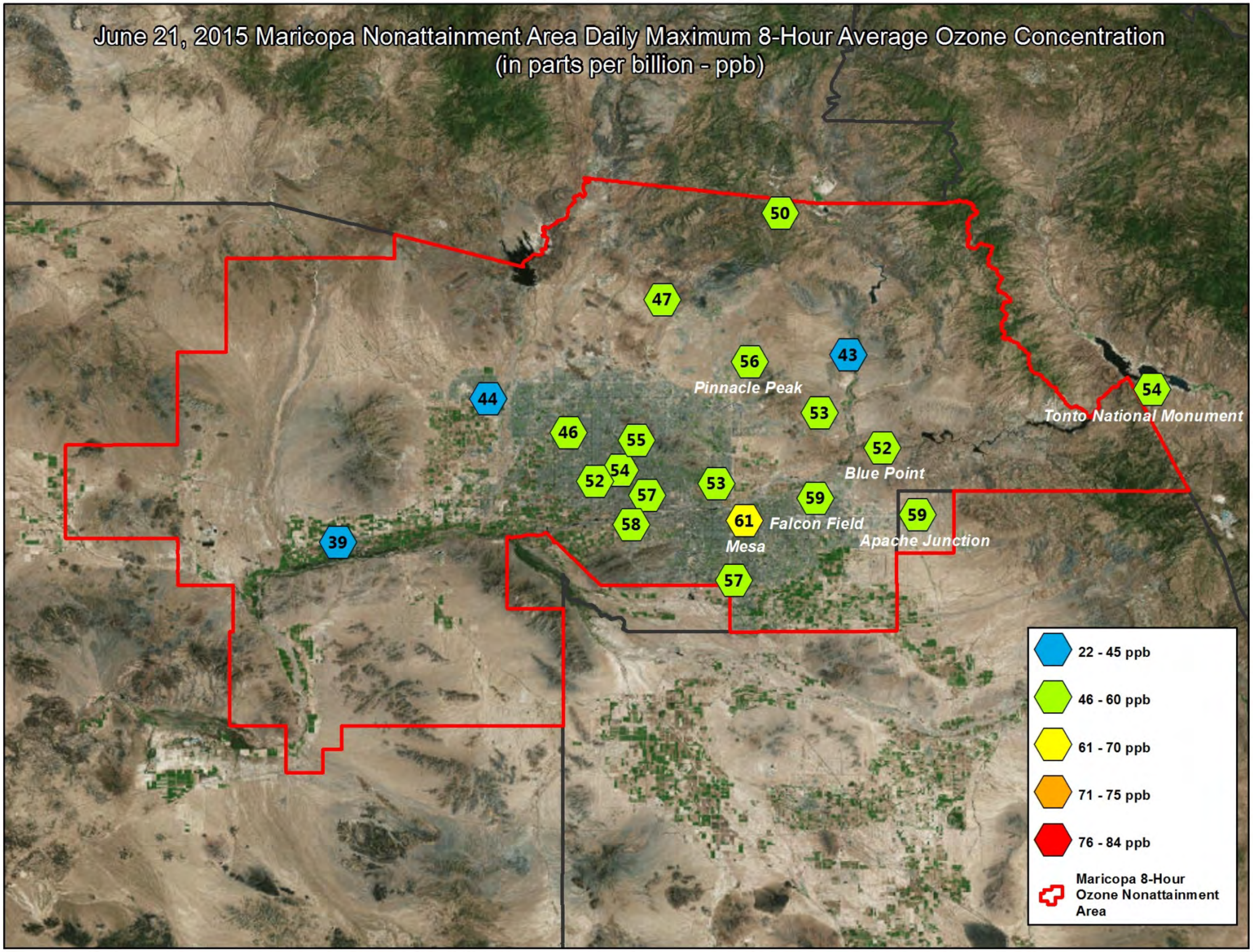

Figure 3-29. Maricopa nonattainment area ozone concentrations on June 21, 2015.

Altered Concentrations of $PM_{2.5}$ and NO_2

In addition to the observed concurrent rise in ozone concentrations, changes to the quantity and timing of $PM_{2.5}$ and NO_2 concentrations were observed in Arizona and the Maricopa nonattainment area. In regard to $PM_{2.5}$, 24-hour average and 1-hour average concentrations of $PM_{2.5}$ were elevated above normal non-event concentrations at the western-most Yuma monitor and at the Alamo Lake monitor, indicating the smoke from the Lake Fire reached ground level at these monitors. Elevated average $PM_{2.5}$ concentrations were not observed in the Maricopa nonattainment area; however speciated $PM_{2.5}$ concentrations do show a higher percentage of organic and elemental carbon as a fraction of $PM_{2.5}$ on June 20, 2015 in this nonattainment area. This indicates that on June 20, 2015, the products of combustion constituted a higher percentage of total $PM_{2.5}$ than seen prior to, and after, the Lake Fire emissions were transported to the nonattainment area. The fact that overall average $PM_{2.5}$ concentrations were not elevated in the nonattainment area is not unexpected given that wildfire researchers Jaffe and Widger[2] found that, "while particulate aerosol concentrations will decrease with distance from a fire, O3 mixing ratios can increase". This finding is corroborated in the $PM_{2.5}$ concentrations from Yuma, Alamo Lake and the nonattainment area during June 18-20, 2015, which show a decrease in $PM_{2.5}$ as emissions from the Lake Fire move west to east across Arizona.

Figure 3–30 displays the hourly average $PM_{2.5}$ concentrations at Yuma and Alamo Lake on June 17-21, 2015, while Figure 3–31 displays the 24-hour average $PM_{2.5}$ concentrations for Yuma and Alamo Lake during June 16-23, 2015. Figure 3–32 includes the speciated fraction of 24-hour $PM_{2.5}$ that is organic and elemental carbon in the Maricopa nonattainment area on a three-day schedule during June 11-29, 2015.

With regard to NO_2, elevated NO_2 concentrations above typical non-event concentrations were recorded at Maricopa nonattainment area monitors, providing additional evidence to indicate that ozone or ozone precursor emissions were transported to the nonattainment area and affected the ozone concentrations seen on June 20, 2015. The normal weekday-weekend pattern in the nonattainment area, as displayed in Figure 3–33, indicates lower NO_2 on Saturdays and Sundays as compared to weekdays. June 20, 2015, was a Saturday, but recorded the highest hourly concentrations of NO_2 for the week. The Maricopa County Air Quality Department confirmed that there were no unusual spikes in anthropogenic sources of NO_x emissions during the period preceding, during, and after June 20, 2015, indicating that extra, non-normal concentrations of NO_2 or ozone were present in the nonattainment area.

Due to the complex diurnal chemical interactions between NO_2 and ozone, where ozone is simultaneously being both produced and consumed, elevated levels of NO_2 at night may indicate the presence of ozone, as opposed to the direct emission of NO_2. NO_2 concentrations were not uniquely elevated at the western Maricopa nonattainment area Buckeye site (rural/suburban site), nor at the rural Alamo Lake site in Western Arizona. As such, the observed high levels of NO_2 in the nonattainment area is likely indicative of ozone and ozone precursors from the Lake Fire reacting with the normal, seasonal emissions present in the Maricopa nonattainment area to form extra NO_2 in the evening (titration) and ozone in the day, as opposed to the direct transport of NO_2 from the Lake Fire to the nonattainment area. This aligns with the findings of Widger et al.,[3] who found that when ozone and ozone precursor emissions from a wildfire interact with urban emissions, increased ozone can form: "Two of the identified wildfire plumes were likely mixed with urban emissions from the Seattle/Tacoma metropolitan area...both of these plumes had significantly higher ΔO3/ΔCO NER than the other plumes in the same distance category...Akagi et al.

[2] *Ibid.*

[3] Widger et al., (2013). Ozone and particulate matter enhancements from regional wildfires observed at Mount Bachelor during 2004-2011. Atmospheric Environment 75, 24-31.

(2013) and Singh et al. (2012) also found significantly higher O3 production in fire plumes mixed with urban emissions, which the studies attributed to higher mixing ratios of NOx produced in urban areas." Figure 3–34 displays the increased hourly NO_2 concentrations at the West Phoenix monitor during June 13-27, 2015 as compared to day-matched June 2010-2014 average historical concentrations.

The elevated levels of NO_2 seen during June 17-20, 2015 also differ from the pattern seen during a non-event ozone exceedance on June 12, 2015 (a Friday). On June 12, 2015, six central and eastern nonattainment area monitors exceeded the standard. Four of the six exceedances were at monitors that also exceeded on June 20, 2015 (Blue Point, Falcon Field, Mesa, and Pinnacle Peak). Hourly NO_2 levels from the West Phoenix monitor were compared on the exceedance day of each episode (June 12 and June 20, 2015), as well as the three days leading up to the episode (June 9-11 and June 17-19, 2015). The results of the comparison show that NO_2 levels on the exceedance day of each episode were similarly high, as would be expected on an exceedance day. However the NO_2 levels leading up to the episodes were much higher for the June 20, 2015 wildfire-event exceedance as opposed to the non-event exceedance on June 12, 2015. This data provides evidence that an additional source of NO_2 (or titrated ozone) was present on the days leading up to the June 20, 2015 exceedance as compared to the non-event exceedance episode on June 12, 2015. Figure 3–35 displays the hourly NO_2 levels on the exceedance day for each episode and the three days prior to the episode exceedance day.

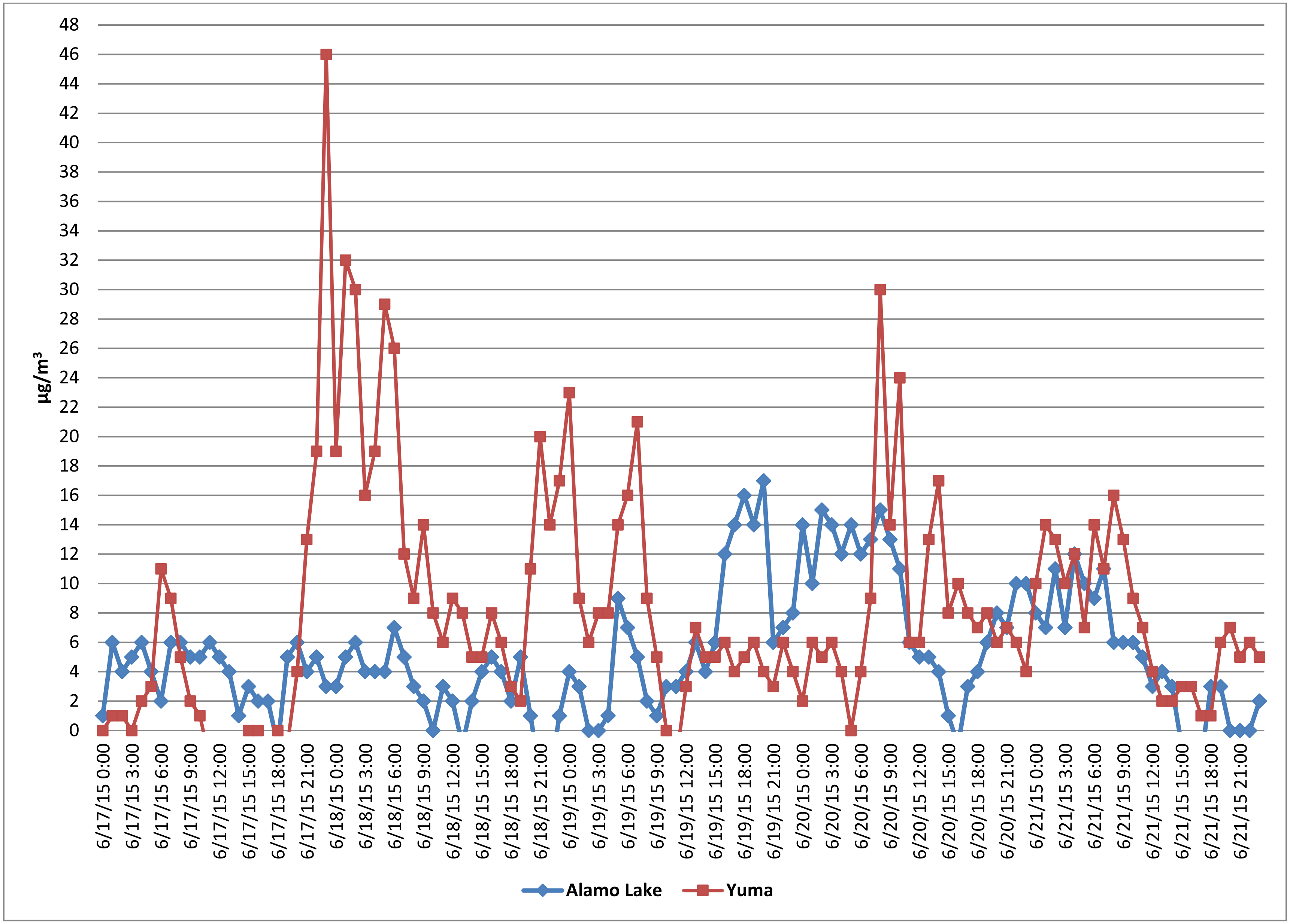

Figure 3-30. Hourly $PM_{2.5}$ concentrations at Alamo Lake and Yuma during June 17-21, 2015.

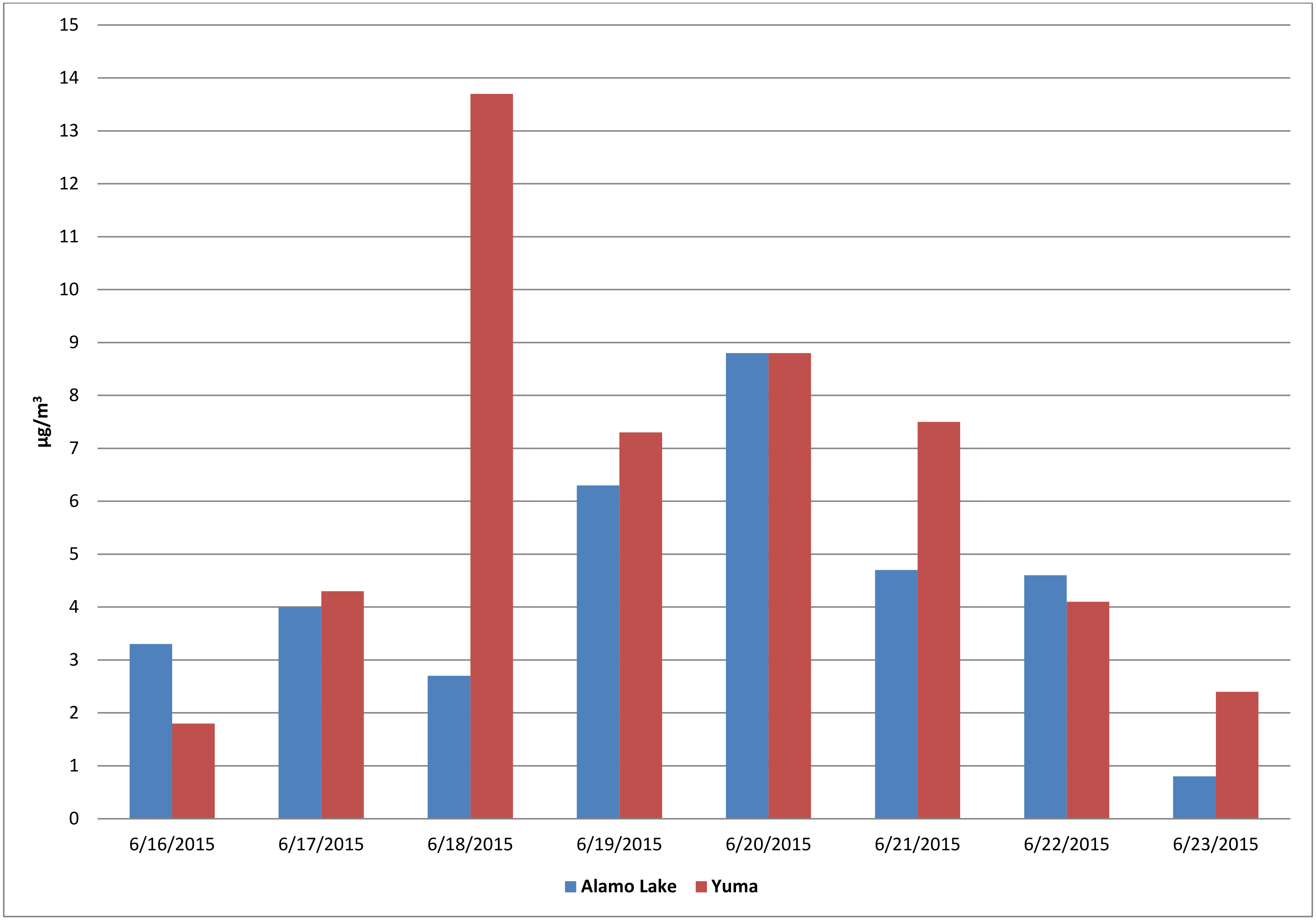

Figure 3-31. 24-Hour $PM_{2.5}$ concentrations at Alamo Lake and Yuma during June 16-23, 2015.

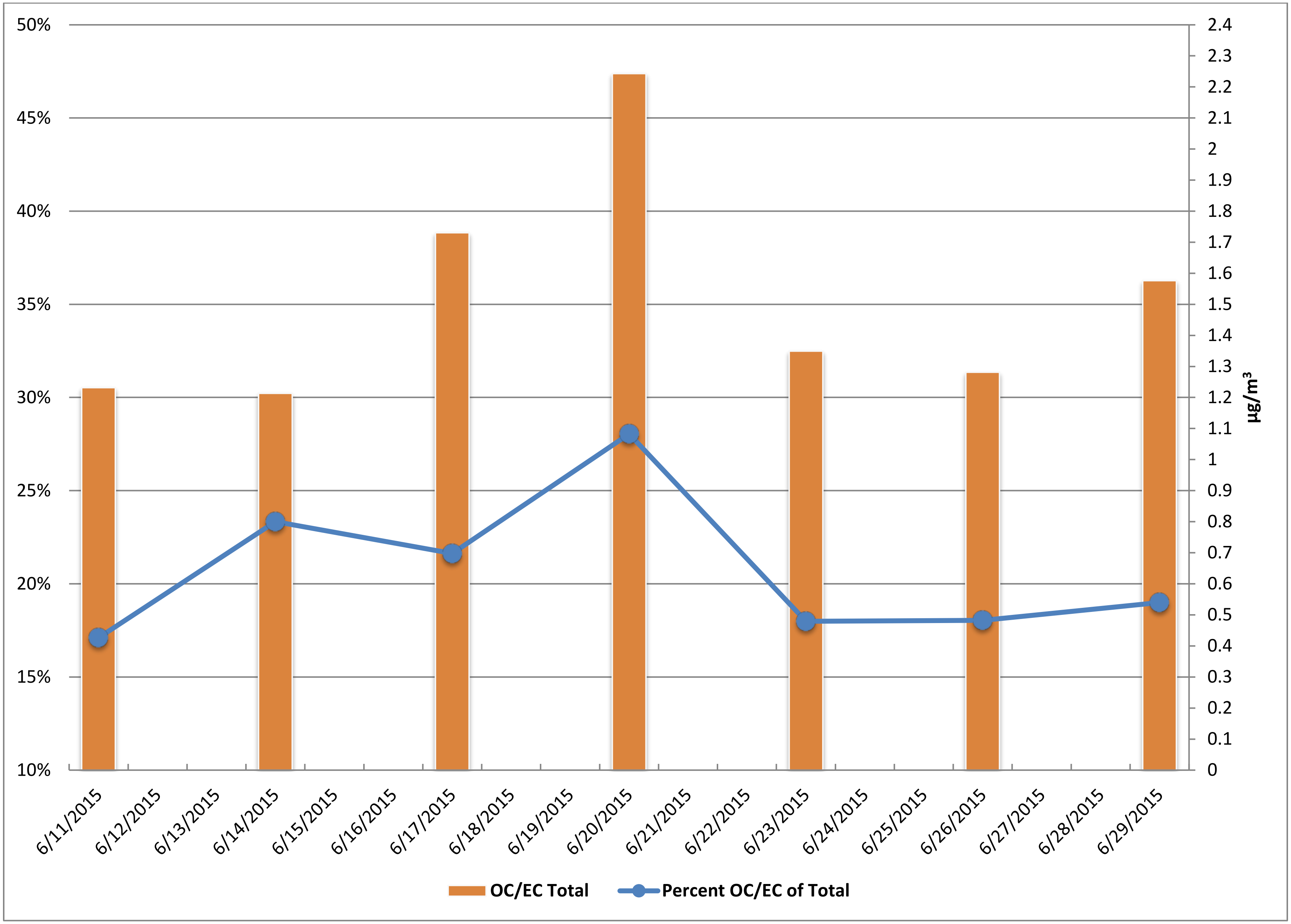

Figure 3-32. Total and percent of 24-hour $PM_{2.5}$ that is organic and elemental carbon at the JLG Supersite monitor.

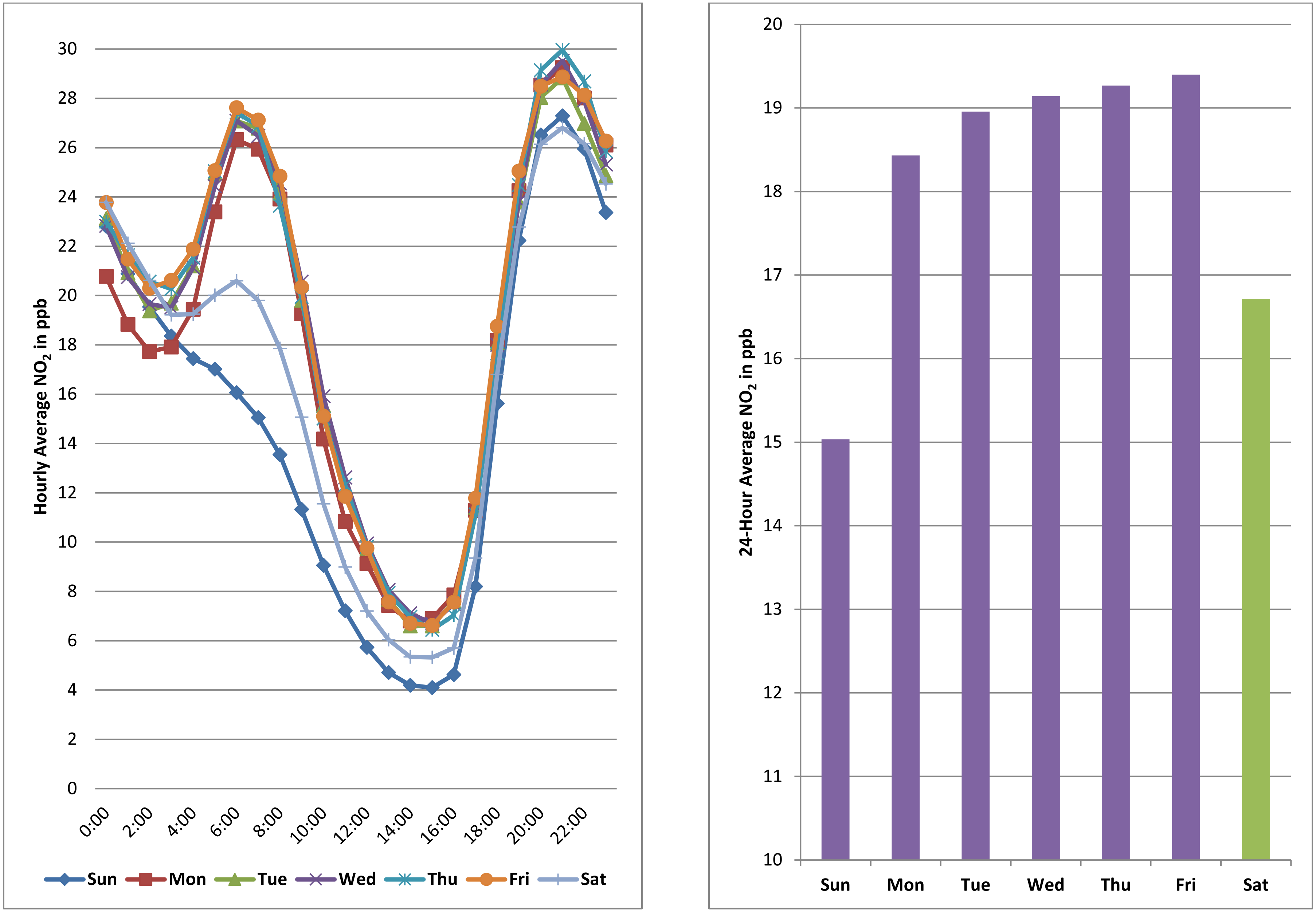

Figure 3-33. June 2010-2014 hourly average and 24-hour average NO_2 by day at the West Phoenix monitor.

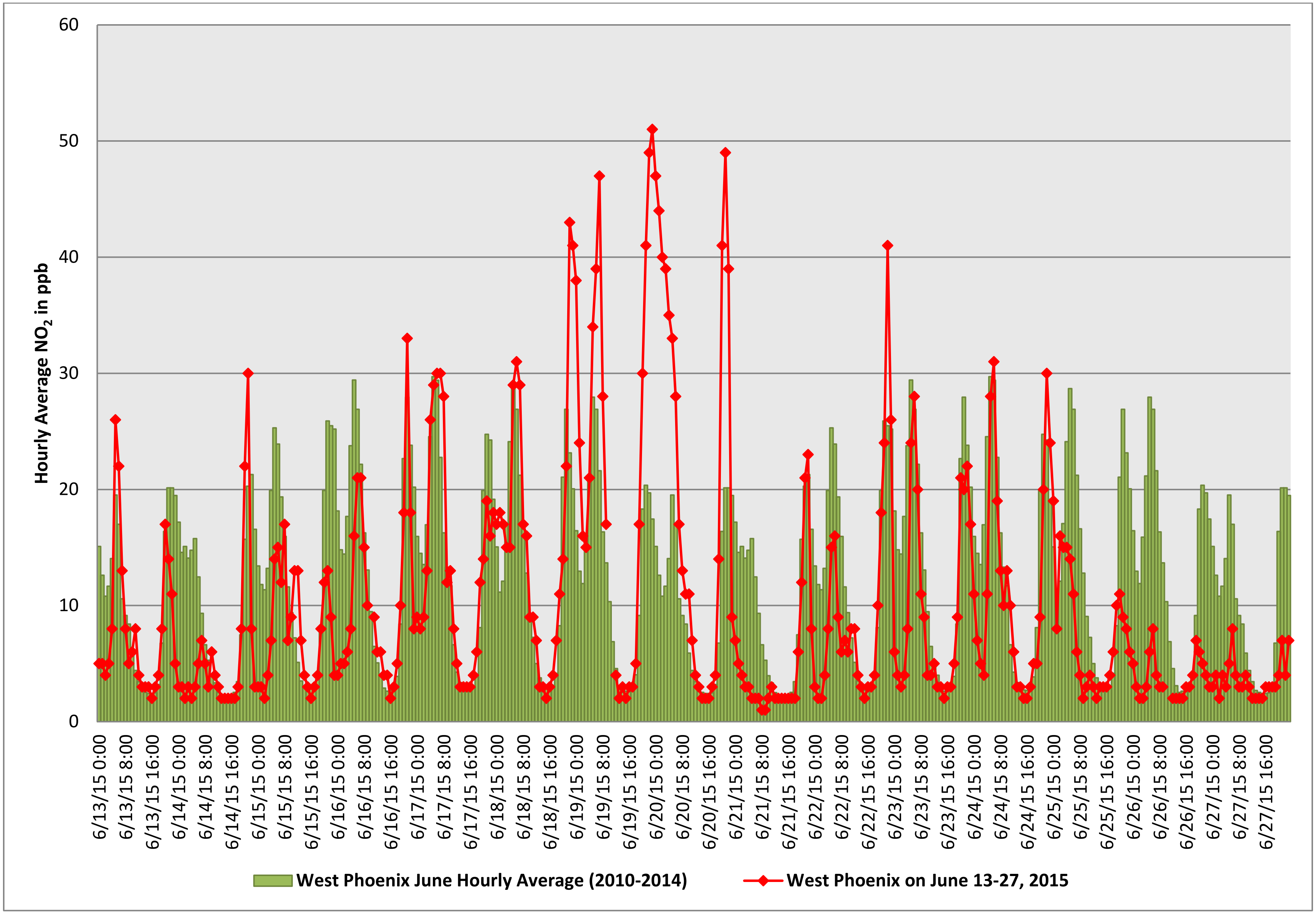

Figure 3-34. Comparison of hourly average NO_2 on June 13-27, 2015 with hourly average June 2010-2014 NO_2 at the West Phoenix monitor.

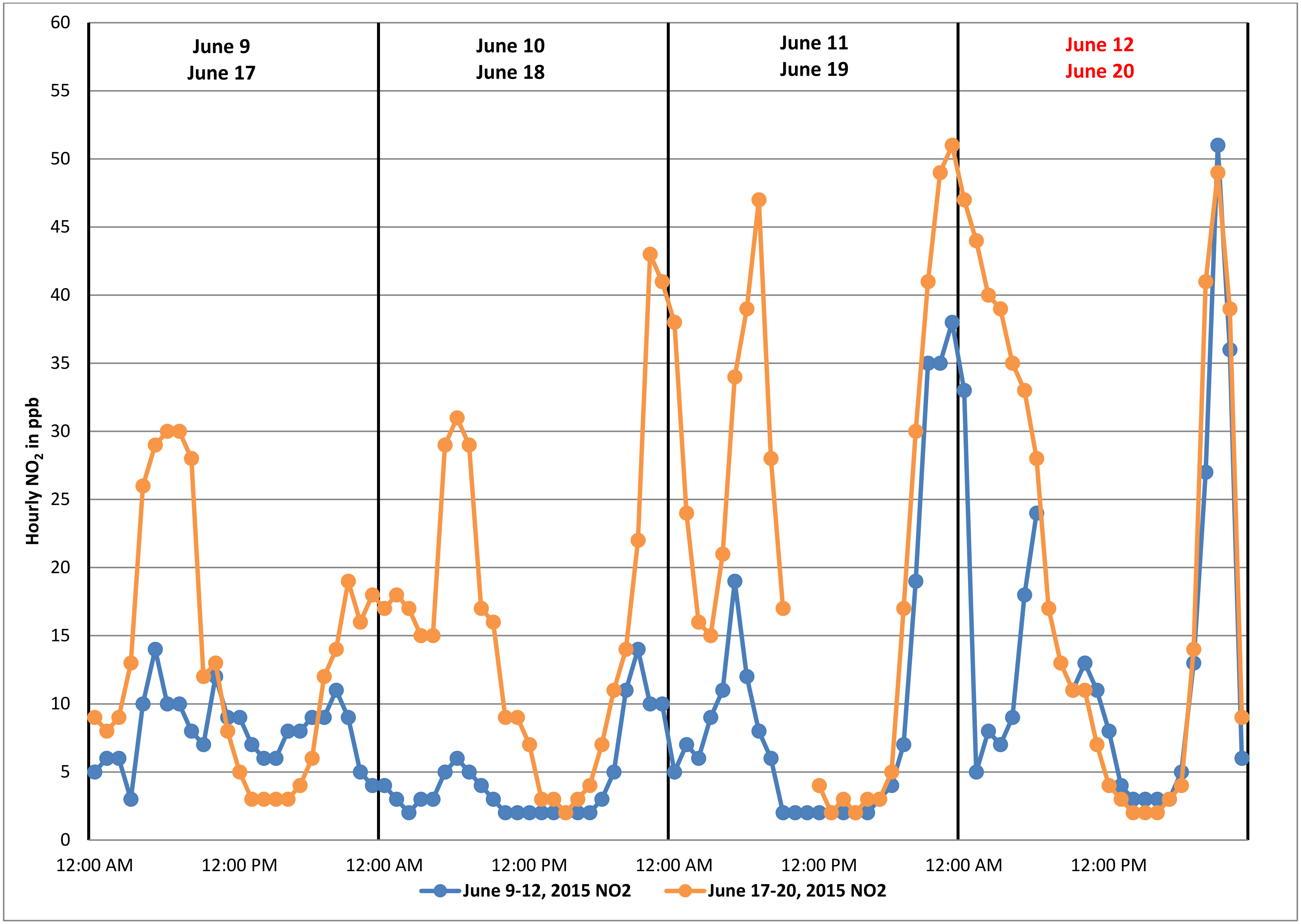

Figure 3-35. Hourly average NO_2 on June 9-12, 2015 and hourly average NO_2 on June 17-20, 2015 at the West Phoenix monitor.

Multiple Variable Regression Analysis ("But For" Demonstration)

In keeping with the Wildfire Guidance suggestion of including an additional source of evidence for Tier 3 demonstrations, multiple variable regression analyses were included in this documentation to add weight to the previously presented evidence of the clear causal connection between the Lake Fire emissions and the exceedances on June 20, 2015. Multiple variable regression analysis is a statistical method for defining and quantifying the relationship of multiple independent variables (e.g., temperature, humidity, and atmospheric pressure) to a dependent variable (ozone concentrations). Using a statistically significant data set (historical ozone concentrations and meteorological data), the results of the regression analysis produce an equation(s) that can then be used to predict the dependent variable (ozone concentrations) given a set of known independent variables (meteorological measurements). When the predicted value deviates substantially from the observed value, the assumption is the observed value is atypical and independent variables other than those already included in the regression analysis (e.g., unusual emissions from a wildfire) are likely responsible for the increase or decrease from the predicted value.

Regression Analysis Development and Performance

For this demonstration, the regression analysis equations used to predict maximum daily eight-hour ozone concentrations at each of the six exceeding monitors on June 20, 2015, were developed using observed meteorological and ozone concentration data in the month of June for the years 2010-2015. A detailed description of the development of the regression analysis is included in Appendix D. Historical data was limited to the month of June, instead of the entire ozone season (April-September), as the other months in the ozone season operate under different meteorological regimes. April and May are frequently influenced by advancing cold fronts that can produce high winds and may contain interstate/international transport of ozone and stratospheric intrusion of ozone. In the months of July-September, the nonattainment area is dominated by monsoon season meteorological conditions which can produce frequent thunderstorms, lightning NO_x and heavy precipitation. In contrast, June is characterized by relatively dry, hot, and low-wind meteorological conditions. For these reasons, historical data for the regression analysis was limited to the month of June.

Over 30 meteorological variables were initially evaluated as independent variables for the regression analysis. All surface meteorological variables (except solar radiation) are taken from measurements at the Sky Harbor International Airport and upper air variables are taken from weather balloons launched at the Tucson International Airport. To avoid including variables that are highly correlated with one another (e.g., maximum surface temperature and average surface temperature), Principal Component Analysis (PCA) was used to group the variables into statistically unique categories. PCA identified eight distinctive categories of meteorological variables. A maximum of two variables from each category were initially selected for the final regression analysis to avoid the statistical problems associated with multicollinearity. Nine variables were ultimately selected from the PCA for inclusion in the regression analysis. The nine selected variables correspond well with variables in other similar regression analyses performed by EPA and other researchers[4]. Table 3–3 includes the nine selected meteorological variables from the Principal Component Analysis.

[4] California Air Resources Board, (2011). Exceptional Events Demonstration for 1-Hour Ozone Exceedances in the Sacramento Regional Nonattainment Area Due to 2008 Wildfires. Camalier et al., (2007). The effects of meteorology on ozone in urban areas and their use in assessing ozone trends. Atmospheric Environment 41, 7127-7137.

In addition to the nine meteorological variables identified in the PCA, categorical variables were also included as independent variables in the regression analysis. The categorical variables include: (1) the wind direction measurements (e.g., west-northwest, east-southeast, etc.) which correspond to the selected wind speed measurements in Table 3–3 to account for air flow direction; and (2) the day of the week (e.g., Monday) to account for differences in emissions between weekdays and weekends. Lastly, one additional scalar independent variable, the prior-day maximum eight-hour average ozone concentration as measured at each exceeding monitor, was also included to account for the effects from the sequential accumulation of ozone in the Maricopa nonattainment area. These variables and their abbreviations are also included in Table 3–3.

Table 3-3. Independent Variables in the Regression Analysis.

Independent Variable Abbreviation	Description
MaxTemp*	Maximum Daily Surface Temperature
UpTemp*	5 am Upper Air (500 mb) Temperature
DiffTemp*	Difference in 5 am Temperature Between Surface and Upper Air (850 mb)
DewPoint*	Average Daily Dew Point
Pressure*	Average Daily Sea-Level Pressure
MornWind*	Average of Morning Hours (6 am to 12 pm) Surface Wind Speed
AftWind*	Average of Afternoon Hours (12 pm to 6 pm) Surface Wind Speed
UpWind*	5 pm Upper Air (850 mb) Wind Speed
Cloud*	Average of Daylight Hours (8 am to 6 pm) Cloud Cover
MornDir	Average of Morning Hours (6 am to 12 pm) Surface Wind Direction
AftDir	Average of Afternoon Hours (12 pm to 6 pm) Surface Wind Direction
UpDir	5 pm Upper Air (850 mb) Wind Direction
Day	Day of the Week
Prior	Prior-Day Maximum Eight-Hour Average Ozone Concentration

**Variable selected from Principal Component Analysis (PCA)*

Using the 14 independent variables listed above and the monitor-specific daily maximum eight-hour average ozone concentration dependent variable, the regression analysis was run for each of the six monitors that exceeded on June 20, 2015. This produces a unique regression equation for each of the exceeding monitoring sites that can be used to predict ozone concentrations with the set of known independent variables. The regression analysis was run to select the best subset of multiple forward stepwise selection runs, based upon the adjusted R^2 criterion in IBM SPSS statistical software, version 21. The adjusted R^2 criterion is based on the fit of the training set, and is adjusted to penalize overly complex models.

Some basic performance statistics of the resulting regression analysis are included in Table 3–4. The overall measure of how well the regression analysis model is able to explain the observed ozone concentration is listed as the adjusted R^2 value. The adjusted R^2 values range from 0.498 to 0.584 and are comparable to adjusted R^2 values seen in other similar analyses using observed meteorological data[5]. The *F*-statistics for all of the models are statistically significant (*p* value less than 0.05), indicating that the independent variables can be relied upon to predict the dependent variable (ozone concentrations). A detailed description of the performance of the regression analysis models is included in Appendix D.

[5] California Air Resources Board, (2011). Exceptional Events Demonstration for 1-Hour Ozone Exceedances in the Sacramento Regional Nonattainment Area Due to 2008 Wildfires. Jaffe et al., (2013). Impact of Wildfires on Ozone Exceptional Events in the Western U.S. Environmental Science & Technology 47, 11065-11072.

Table 3-4. Regression Analysis Basic Performance Statistics.

Monitor	Adjusted. R^2	*F*	Significance (*p*)
Apache Junction – Model Summary	0.559	25.632	0.000
Blue Point – Model Summary	0.508	18.966	0.000
Falcon Field – Model Summary	0.493	16.379	0.000
Mesa – Model Summary	0.562	10.213	0.000
Pinnacle Peak – Model Summary	0.498	14.054	0.000
Tonto Nat. Monument – Model Summary	0.584	19.052	0.000

A list of the coefficient, importance, *t*-statistic, *p* value, and standard error of the independent variables for each of the six exceeding monitors' regression analysis models is included in Table D–6 of Appendix D. The independent variables that are included in each monitoring site's regression analysis are not identical in each model. This is not unexpected given that the monitoring sites are situated in disparate locations including dense-urban areas (Mesa), suburban areas (Pinnacle Peak) and rural locations (Tonto National Monument), which allow for different interactions between meteorology and the NO_X and VOC precursor emissions that lead to ozone formation. Despite some variation, all monitoring sites were significantly influenced by the prior day ozone concentration, atmospheric stability and/or pressure measurements, and multiple wind speed and direction measurements.

Regression Analysis Results

The results of the regression analysis for each of the monitoring sites predict maximum daily eight-hour ozone values on June 20, 2015 between 0.065 and 0.070 ppm (values truncated to three decimal points in keeping with the form of the standard), well below the 2008 ozone standard of 0.075 ppm. The results confirm the assumption that under the meteorological conditions that existed on June 20, 2015, the monitors would normally not have exceeded the 2008 ozone standard, and suggests that an out-of-the-norm variable (e.g., increased emissions from the wildfire) influenced the ozone concentrations on June 20, 2015. The difference between the observed and predicted ozone concentrations can be used to infer the amount of additional ozone created by the wildfire emissions. Using this as a metric, the wildfire is estimated to have contributed additional ozone concentrations of between 0.008 ppm to 0.013 ppm on June 20, 2015. These results provide evidence to support the assertion that the exceedances on June 20, 2015 would not have occurred "but for" the additional ozone and ozone precursor emissions created by the Lake Fire.

The robustness of this result can also be investigated by comparing the differences between all of the observed ozone concentrations and all of the predicted ozone concentrations in the regression analyses datasets. This provides a method to evaluate how much of a departure the exceeding (observed) concentrations are as compared to the expected (predicted) concentrations (i.e., statistically identifying how rare the observed concentrations are). The positive difference (when the model predicts a concentration that is less than the observed concentration) between the observed and predicted ozone concentration on June 20, 2015 can be compared to all of the recorded positive differences in the regression analysis data set (2010-2015) by assigning a percentile rank to the June 20, 2015 positive difference. Since we are not interested in those days when the model predicts a concentration that is higher than the observed concentration, days with negative differences are not included in the percentile rankings.

The percentile rank of the positive differences between the observed and predicted ozone concentrations for each of the exceeding six monitors on June 20, 2015 range from the 83rd to the 92nd percentile. This means that on average, the regression analysis indicates there is only a 8 to 17 percent chance that the positive difference between the observed and predicted ozone concentrations recorded at the six exceeding monitors would be produced under the meteorological conditions that existed on June 20, 2015. As such, the regression analysis results provide another piece of evidence, when viewed in context of the whole body of evidence, which points to the significant contribution of the Lake Fire emissions to the ozone concentrations at the exceeding monitors in the Maricopa nonattainment area on June 20, 2015. Table 3–5 contains the observed and predicted ozone concentrations for June 20, 2015, the difference between the observed and the predicted concentrations, and the percentile ranking of the difference for each of the exceeding monitors. Additional information and examination of the regression analysis results are included in Appendix D.

Table 3-5. Regression Analysis Results.

Monitor	Observed Ozone Concentration on June 20, 2015	Predicted Ozone Concentration on June 20, 2015	Difference Between Observed and Predicted Ozone Concentrations	Percentile Rank of Positive Difference
Apache Junction	0.078 ppm	0.065 ppm	0.013 ppm	92nd
Blue Point	0.077 ppm	0.065 ppm	0.012 ppm	91st
Falcon Field	0.080 ppm	0.068 ppm	0.012 ppm	89th
Mesa	0.079 ppm	0.069 ppm	0.010 ppm	84th
Pinnacle Peak	0.078 ppm	0.070 ppm	0.008 ppm	83rd
Tonto Nat. Monument	0.079 ppm	0.070 ppm	0.009 ppm	84th

IV. NATURAL EVENT AND NOT REASONABLY CONTROLLABLE OR PREVENTABLE CRITERIA

Natural Event

Clean Air Act Section 319(b)(1)(A)(iii) defines an exceptional event as "an event caused by human activity that is unlikely to recur at a particular location or a natural event". The current exceptional events rule at 40 CFR Section 50.14(c)(3)(iv)(A) requires that evidence be provided in an exceptional event demonstration that this definition has been met. EPA's proposed revisions to the exceptional events rule defines a wildfire as "any fire started by an unplanned ignition caused by lightning; volcanoes; other acts of nature; unauthorized activity; or accidental, human-caused actions, or a prescribed fire that has been declared to be a wildfire. A wildfire that predominantly occurs on wildland is a natural event." The proposed revisions define wildland as "an area in which human activity and development is essentially non-existent, except for roads, railroads, power lines, and similar transportation facilities. Structures, if any, are widely scattered." Lastly, in the Wildfire Guidance, EPA states that "the EPA believes that treating all wildfires on wildland as natural events is consistent with the CAA and the EER."

Based on the documentation provided in Section II of this submittal, the event meets the definition of a wildfire, as the Lake Fire was caused by unauthorized human activity in the wildland areas of the San Bernardino National Forest. As EPA considers all wildfires to be natural events, the event that caused the ozone exceedances in the Maricopa nonattainment area on June 20, 2015 therefore qualifies as a natural event.

Not Reasonably Controllable or Preventable

Clean Air Act Section 319(b)(1)(A)(ii) requires that an exceptional event be "not reasonably controllable or preventable". The current exceptional events rule at 40 CFR Section 50.14(c)(3)(iv)(A) also requires that evidence be provided in an exceptional event demonstration that the event was not reasonably controllable or preventable. This criterion applies to both natural events and events caused by human activity unlikely to recur.

The proposed revisions to the exceptional events rule clarify that the documentation of the event must demonstrate that the event was both not reasonably controllable and not reasonably preventable. Both the Wildfire Guidance and the proposed revisions to the exceptional events rule presume that wildfires on wildlands satisfy both of these factors. Since the Lake Fire has been shown to be a wildfire on wildland in prior sections of this submittal, the exceedances on June 20, 2015 are therefore neither reasonably controllable nor preventable. Additionally since the wildfire occurred on wildland outside of the state of Arizona (southeastern California), the state of Arizona has no means to prevent the wildfire from occurring or to prevent the transport of ozone and ozone precursor emissions from the fire which caused the exceedances on June 20, 2015 in the Maricopa nonattainment area.

V. SUMMARY CONCLUSION

The documentation presented above provides ample weight of evidence that the six exceedances of the 2008 ozone standard on June 20, 2015 in (or very near) the Maricopa eight-hour ozone nonattainment area were caused by transported ozone and ozone precursor emissions from the southern California Lake Fire, qualifying these exceedances for exclusion under the exceptional events rule. A bulleted summary of the documentation is provided below:

- The event affected air quality at the exceeding monitors as evidenced by a historical comparison of the ozone concentrations at the exceeding monitors. This comparison indicated that the exceedances on June 20, 2015 were either at or above the 99^{th} percentile, or the exceedance was one of the top three highest concentrations recorded in 2015. Evidence presented in support of a clear causal relationship between the June 20, 2015 exceedances and the transported ozone and ozone precursor emissions from the Lake Fire forms a link between the affected air quality at the exceeding monitors and the Lake Fire emissions.

- The conceptual model discussion of how the Lake Fire emissions affected ozone concentrations in the Maricopa nonattainment area and the clear causal relationship between the six exceedances in the Maricopa nonattainment area and the transported ozone and ozone precursor emissions from the Lake Fire is established through:

  (1) Maps and documentation showing the location and extent of the Lake Fire during June 17-June 20, 2015;
  (2) A discussion of the rapid growth of the Lake Fire on June 18, 2015 and June 19, 2015 showing that the majority of the emissions from the Lake Fire that affected Arizona and the nonattainment area were emitted on June 18, 2015 and June 19, 2015;
  (3) Satellite photos of transported smoke across Arizona preceding the exceedances;
  (4) Daily upper and lower level wind maps detailing the prevailing transport of air from the Lake Fire to the Maricopa nonattainment area;
  (5) Calculation of the daily VOC and NOx emissions from the Lake Fire and the daily Q/D ratios on June 17-19, 2015;
  (6) Hysplit back trajectories confirming air movement from the Lake Fire area to the nonattainment area at lower and upper altitudes;
  (7) NOAA smoke maps showing the dispersion of smoke across Arizona on June 17-20, 2015;
  (8) Coinciding rise in ozone concentrations across northern and central Arizona and the Maricopa nonattainment area as ozone and ozone precursor emissions from the Lake Fire transported from California to Arizona and the nonattainment area;
  (9) Elevated concentrations of PM2.5 in the western Arizona areas of Yuma and Alamo Lake coinciding with transport from the Lake Fire;
  (10) A Higher percentage of organic and elemental carbon as a portion of $PM_{2.5}$ concentrations in the Maricopa nonattainment area;
  (11) Unusually high concentrations of NO2 on June 20, 2015 (a Saturday) in the nonattainment that differ from the standard weekday-weekend pattern observed in June, indicating the presence of an additional source of ozone or ozone precursors emissions;
  (12) Increased levels of NO_2 on the days preceding the June 20, 2015 exceedances as compared to the days preceding a non-event exceedance on June 12, 2015; and

(13) A regression analysis providing evidence that the ozone concentrations recorded on June 20, 2015 were statistically likely to be produced on average only 8 to 17 percent of the time under the meteorological conditions that were present in the nonattainment area on June 20, 2015. The regression analysis predicted ozone concentrations without the influence of the Lake Fire emissions at 0.065 to .070 ppm, well below the 2008 ozone standard of 0.075 ppm, providing evidence that the exceedances were unlikely to occur "but for" the additional transported ozone and ozone precursor emissions created by the Lake Fire.

- The event is a natural event. Wildfires on wildlands (whether caused by human activity or natural activity) are acknowledged as natural events in the Wildfire Guidance and the proposed revisions to the exceptional events rule.

- The event was neither reasonably controllable nor preventable, as the State of Arizona cannot control or prevent the ignition of a wildfire and the subsequent transport of ozone and ozone precursor emissions into Arizona and the nonattainment area from a wildfire in southeastern California.